SAE journal

JUNE 1959

IN THIS ISSUE . . .

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SAE journal

Society of Automotive Engineers

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Society Headquarters
Editorial and Advertising Office
485 Lexington Ave., New York 17, N. Y.
Tel: OXford 7-3340; Teletype: NY1 228

Detroit Branch manager, G. J. Gaudaen
635 New Center Bldg., Detroit 2, Mich.
Tel: TRinity 1-1772; Teletype: DE 826

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714 W. Olympic Blvd., Los Angeles 15, Cal.
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Departments

READERSHIP RESEARCH

A complete index of all Journal technical articles, from January through December, will appear in the December issue. All Journal technical articles are indexed by Engineering Index, Inc. SAE Journal is available on microfilm from University Microfilms, Ann Arbor, Mich.

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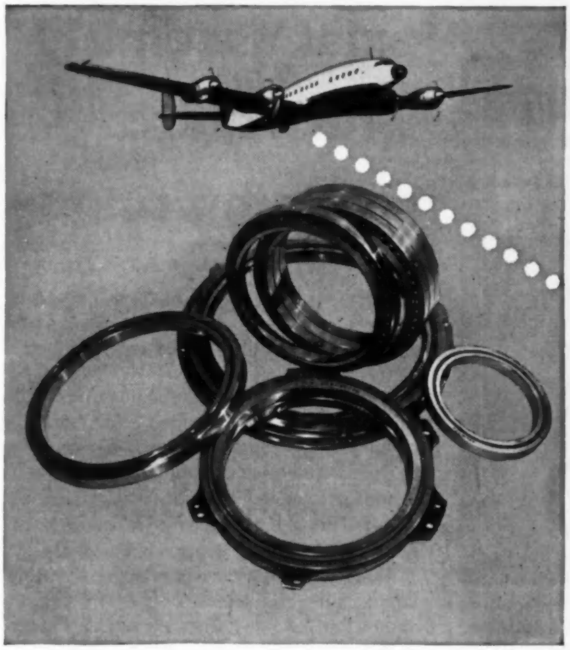

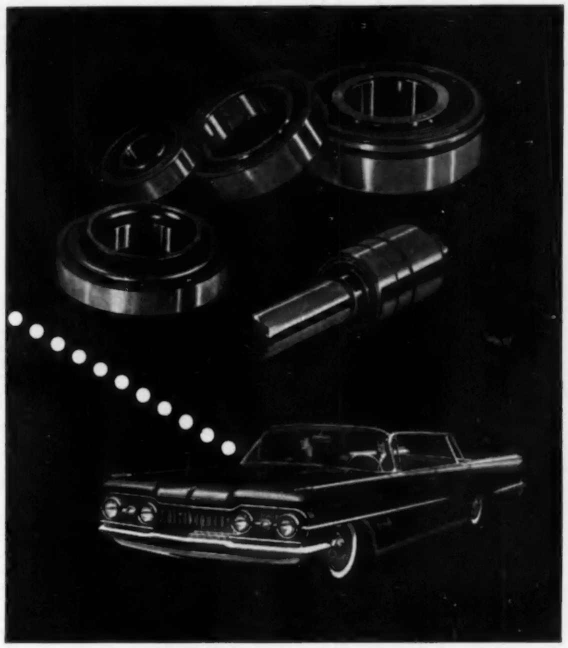

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Briefs of SAE PAPERS

Presented here are brief digests of recently presented SAE papers. These papers are available in full in multilith form for one year after presentation. To order, circle the numbers in the "Readers Information Service" blank on page 6 corresponding to the numbers appearing after the titles of the digests of interest to you.

AIRCRAFT

Handling Commercial Jet Airplane on Ground. J. F. HORAN. Paper No. 48R. Performance of ground services for Boeing 707 jet transport depends on following factors: system design in aircraft, trained ground personnel, ground equipment, and efficient procedures; two methods of fueling: under-wing pressure filling and over-wing gravity filling; engine servicing and effect of various starting methods on terminal operation; other aspects such as galley servicing, potable water provision, ground air conditioning, etc.

Continuous Air Source Packs for Jet Engine Starting and Air Conditioning, F. P. CARR, Jr., S. KALIKOFF. Paper No. 48S. Requirements for starting turbojet and turboprop engines, and for cooling cabins on commercial aircraft using them; pneumatic service units fall into three classes: units whose sole function is starting engines, carts which supply conditioned air to cabin for passenger comfort, and combination units which contain various permutations of engine starting plus air conditioning equipment; each class and subgroups are considered.

Design Approach to Allison Model 250 Engine, R. S. HALL. Paper No. 49R. Technical considerations involved in determination of 250-hp engine design, developed by General Motors for small helicopters and light military aircraft; unique features are reviewed such as free turbine, selection of engine pressure ratio and turbine inlet temperature, engine air flow, matching of components, selection of compressor configuration, control system, and mechanical configuration.

Anti-Icing for Gas Turbine Helicopter Engine—Development of System T53, T. A. DICKEY, O. DUMLER, J. R. UNTIED. Paper No. 49S. Design considerations, thermal characteristics, development experience, and final results of development of hot air system for T53—free turbine shaft power gas turbine engine in 860 to 1000-hp class; layout of hot air circuit used for T53-L-1 model and system for T53-L-3 engine, augmented by series circuit (inlet housing wall), which supplies struts and augments flow to guide vanes; characteristics of two systems.

NASA Research Bearing on Jet Engine Reliability, S. S. MANSON, G. M. AULT, B. PINKEL. Paper No. 49T. Review of highlights of studies described in NACA—Research Memo No. E 55H02, declassified July 1958, which presents finding of Lewis Research Center's study on factors that affect operational reliability of turbojet engines; results of additional studies are summarized and their significance in relation to turbojet operational reliability interpreted; principal causes of jet engine damage and failure. 23 refs.

Seals, Vulnerable Giants, C. E. HAMLIN. Paper No. 50S. Approach taken by Autonetics, Div. of North American Aviation, in establishing requirements of 500 F missiles hydraulic system; various classes of fluids under consideration for high temperature usage; limitations on use of organic elastomeric seals; metalic seals for dynamic applications, still in developmental stage; use of ductile iron (mechanite) for piston and shaft seals, and static boss seal fabricated from stainless steel, Inconel X and aluminum; test results.

How to Apply Human Engineering Principles to Maintainability Design of Weapon Systems, G. F. RABIDEAU. Paper No. 51R. Increasing problem of weapon system maintainability with respect to military aircraft is considered and attempt made to categorize

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Briefs of SAE PAPERS

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maintenance design deficiencies; corrective human engineering principles; method, applied at Northrop Corp., is proposed for application of human engineering principles to maintainability design and step-by-step specification pointing out deficiency areas.

Relaxed Alertness in Cockpit, J. LEDERER. Paper No. 51S. Opinion survey conducted by Flight Safety Foundation of Cornell-Guggenheim Aviation Safety Center, on problem of retaining crew vigilance; environmental and subjective factors; it is suggested that design of cockpits should be treated on integrated basis with objective to avoid soporific monotony, distractions, discomfort, restlessness considering effect of one component on other and of all on crew; aspects treated include visibility, ventilation, controls, noise, etc.

Trends in Powered Ground Support Equipment for USAF, C. R. CARROLL. Paper No. 7S. For jet aircraft support equipment includes: electric power supplies, checkout equipment, test and run-up stands for engines, fueling trailers, liquid oxygen generation and storage equipment, air conditioning, and l-p, high volume air compressors for starting; requirements for special applications are considered for electrical power systems up to 150–200 kw; frequency regulation problems; use of gas turbines.

Fairchild F-27 Turbine Transport Progress Report, W. H. ARATA, Jr. Paper No. S162. Features of high-wing, propjet-powered Business Transport version of Fairchild F-27 with normal complement of 16 passengers in basic executive interior manufactured by Fairchild Aircraft and Missiles Div., Hagerstown, Md.; plane is powered with either Rolls-Royce Dart 6/Mk 511 or Rolls-Royce 7/Mk 528 engine; details of operational, interior, and optional features; performance history. 23 fig.

COMPUTERS

Becoming Acquainted with SACIO, A. D. HESTENES. Paper No. 39R. Features of modern computer's electronic data processing equipment components termed "SACIO" (storage, arithmetic and logic, control, input, and output); function of this equipment and flow of information and control through system are explained.

FUELS & LUBRICANTS

Effects of Kerosene Type Fuels on Design and Operation of Jet Transport, F. K. BRUNTON, J. C. DEWEESE. Paper No. 47R. Of 25 fuel properties, those having greatest influence on aircraft design are: freeze point and viscosity, water solubility, vapor pressure, heat of combustion, weight, and properties which affect elastomers; experience at Pan American World Airways with Boeing Model 707-121 jet transports as regards control of fuel quality, sump checks, fuel anti-icing, fuel temperature, filtration, and refueling equipment.

Orenda Engine Experience with Service Fuels, A. S. SUTTON. Paper No. 47S. Fuel contamination effects that have occurred in over million hours of service flying using JP-4 fuel in fighter aircraft; description of Orenda fuel system; parts that are more susceptible to contamination are considered including small orifices, servo half-balls, close tolerance sliding surfaces, centrifugal separator areas and fuel pump; review of failed pumps and improved pump; filter experience; steps to provide protection within fuel system.

Can We Define Aircraft Turbine Fuel Cleanliness Requirements? G. T. COKER, H. R. HEIPLE, R. G. DAVIES. Paper No. 47T. Problem of fuel contamination; techniques for measuring dirt in laboratory and for sampling in field, and results of field surveys with JP-3 fuel; it is found that concentration of particle contaminants becomes less as fuel is moved through distribution and dispensing systems from terminal storage to aircraft; need of

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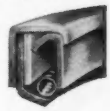
NATIONAL OIL SEAL LOGBOOK

Oil Seal Selector Chart

The data given below indicate, for most common applications, the type of oil seal that will operate best under given conditions. Where one or more parameters are extreme, modified or special seals may be required. For engineering help or availability details, call the nearest National Seal Engineer. Look under Oil Seals, in the Yellow Pages.



50,000 series
Micro-Torc
Leather

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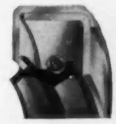
Syntech
Synthetic



410,000 series
Syntech
Synthetic

		50,000 series Micro-Torc Leather	450,000 series Syntech Synthetic	410,000 series Syntech Synthetic
MATERIAL SEALED	Mineral base oils and greases are most common materials. Availability of lubricant, criticalness of service, and cleanliness strongly influence construction choice. National Micro-Torc leather seals are recommended for grease and oil applications and particularly where semi-starved lubricant conditions may exist. For oil and fluid "zero leakage" service Syntech seals are normally considered. For applications involving both "zero leakage" and heavy dirt conditions, the user may wish to consider dual lip Syntech seals.			
SHAFT SPEED	Prime factor in seal selection. Governs all other factors. Shown in FEET PER MINUTE AS SLOW, MODERATE, HIGH.			
FPM	Slow	0 to 800	0 to 1000	0 to 1000
	Moderate	800 to 1500	1000 to 2000	1000 to 2000
	High	1500 to 2000	2000 to 3000	2000 to 3000
TEMPERATURE	Limits shown are points where sealing material or medium sealed becomes ineffective. For sealing under extreme temperature conditions, special compounds can be employed.			
LIMITS °F.	Continuous	−65° +200°	−65° +225°	−65° +225°
	Intermittent	−65° +225°	−60° +250°	−60° +250°
PRESSURE	Conventional oil seals are not pressure seals. Where pressures above those shown exist, special seals should be employed or pressure against sealing lip relieved.			
MAXIMUM PSI	Slow	15	10	10
	Moderate	10	7	7
	High	5	5	5
SHAFT FINISH	Fineness and type of finish, direction and spiral of finishing marks and leads as well as RMS value affect sealing. Polished or ground finishes with concentric finish marks are preferred.			
MAXIMUM MICRO INCHES	Slow	25	25	25
	Moderate	20	20	20
	High	20	20	20
SHAFT HARDNESS	Although shafts as soft as cold rolled steel can be sealed successfully, hardness of C20 Rockwell or greater is preferred. Fluid starvation, abrasives and high surface speeds require hard shafts.			
SUGGESTED ROCKWELL	Abrasives	above C-45	above C-45	above C-45
	No abrasives	above B-80	above B-80	above B-80
SHAFT TO BORE MISALIGNMENT	Fixed misalignment of center of shaft rotation with bore center. Concentrates wear at one side of seal. Becomes more severe as speed increases.			
TOTAL INDICATOR	Slow	.010	.015	.015
	Moderate	.005	.010	.010
	High	.005	.010	.010
SHAFT RUN-OUT	Oscillating non-concentricity between shaft and bore centers (also eccentricity or shaft whip). Run-out should be kept to absolute minimum; creates difficult sealing problem.			
TOTAL INDICATOR RPM	0-800	.010	.025	.025
	800-2200	.005	.020	.020
	2200-4200	.003	.015	.015

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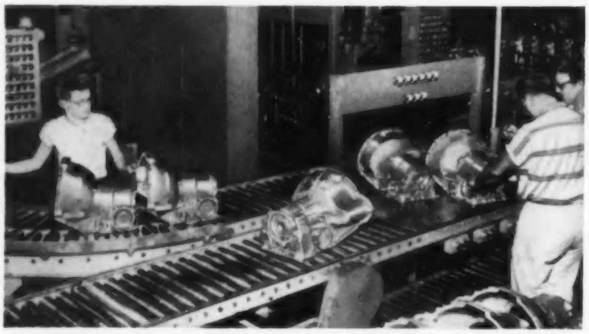
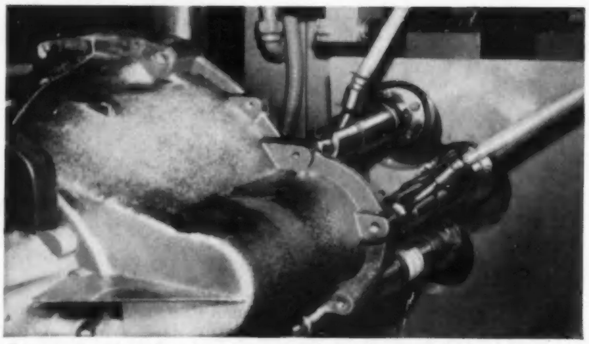
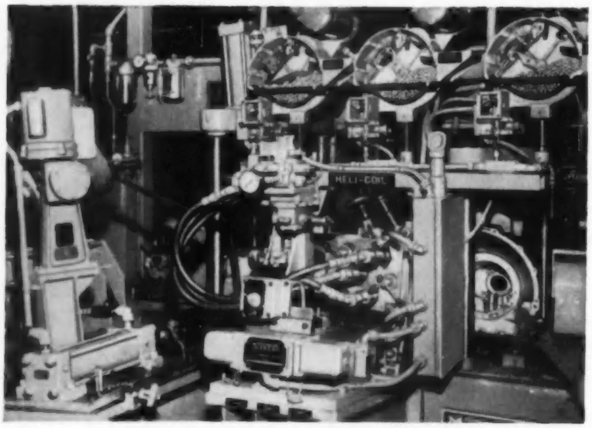
FORD Aluminum Transmission Housings get permanent steel thread strength with HELI-COIL® Screw-Thread Inserts



Aluminum housings are drilled and tapped, then transferred to *Heli-Coil* inserting machines on Ford assembly line. Each machine automatically and simultaneously installs three 5/16-18 Screw-Thread Inserts in seconds.



Inserts are picked up by air-powered rotating mandrels and wound into housing.



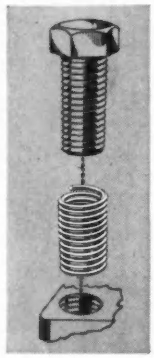
Hoppers over the inserting machine have 1500 insert capacity. Air jets speed inserts as they slide through nylon tubes into the inserting tools. Unit was specially designed and built by *Heli-Coil* Corporation as an integral part of the Ford production line and is the first completely automatic inserting machine to have all operations co-ordinated into a single unit.

Automatic inserting machines speed installation on production lines

Tapped threads in the starter mounting pad of this new Ford aluminum transmission housing would have been too soft to resist wear caused by vibration, impact and occasional dismantling for service.

Ford Motor Company uses one-piece ***Heli-Coil*** Screw-Thread Inserts for greater thread strength under dynamic and static loading. With these precision-formed steel wire threads, there's *no* chance of thread wear or stripping for the life of the transmission.

Heli-Coil engineers designed and built high-speed equipment to install the inserts *automatically* right on the transfer line. There's no production slowdown.



Heli-Coil Inserts

- allow repeated assembly and disassembly without loss of thread strength
- hold screws or studs securely under vibration and impact
- prevent thread wear, stripping, corrosion, galling and seizing
- can be used in standard proportion bosses without need for redesign
- are available in a complete range of U.N.C. and U.N.F. thread sizes as well as spark plug and pipe thread series
- save assembly time, space, weight and cost.

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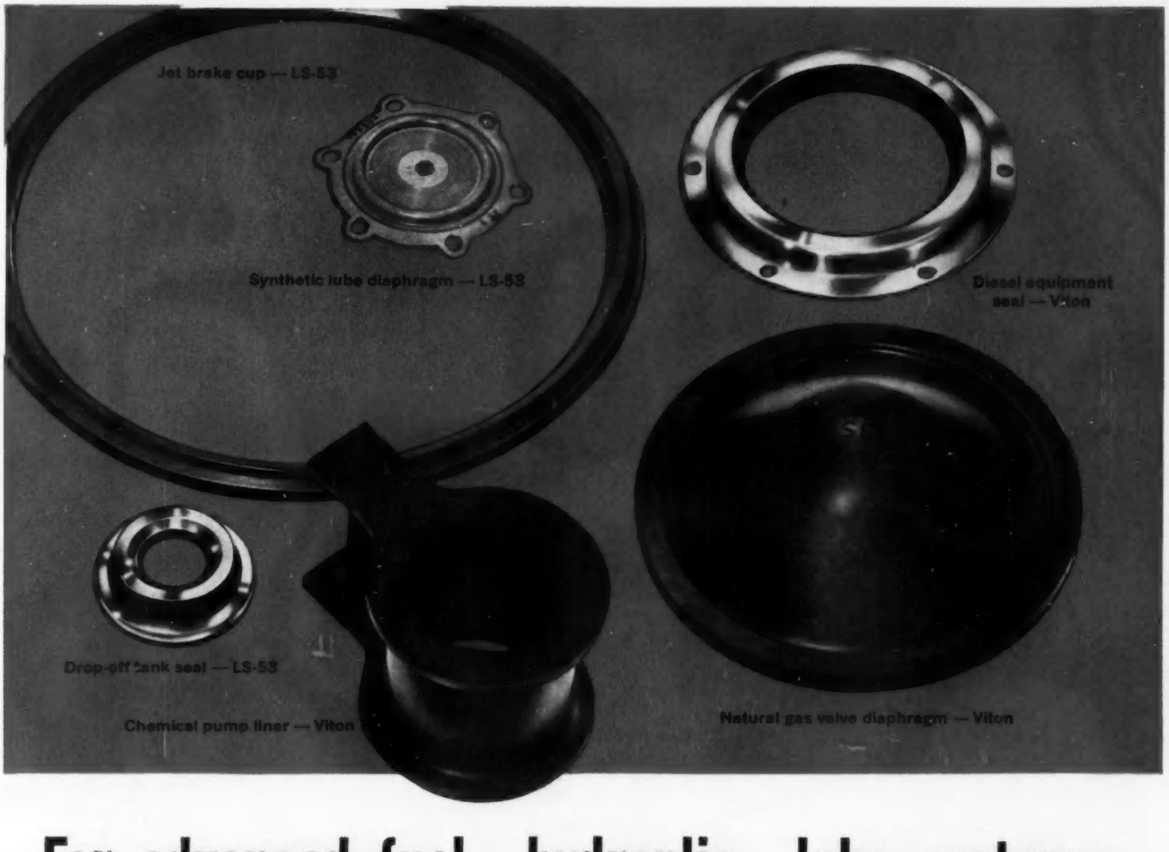

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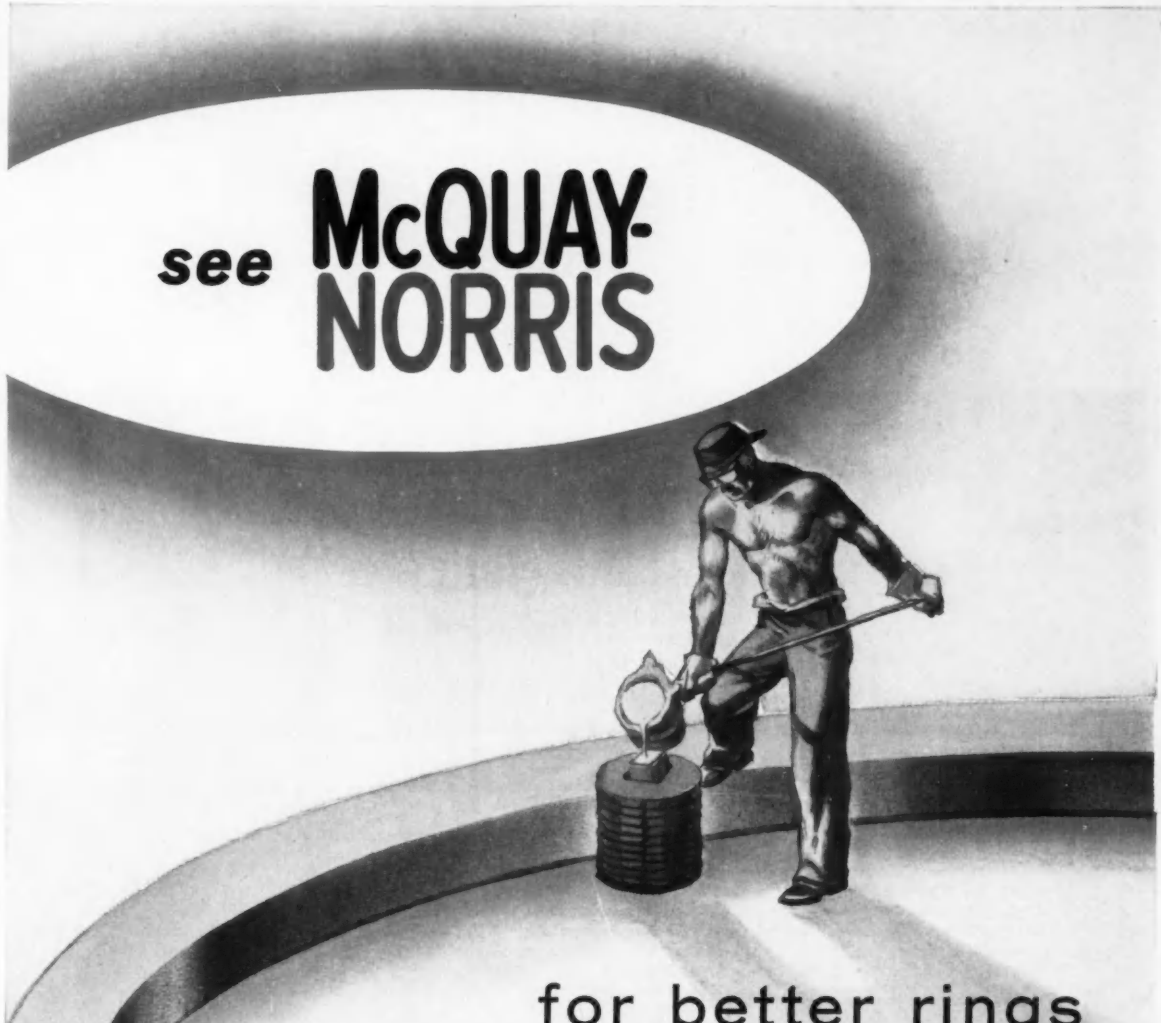
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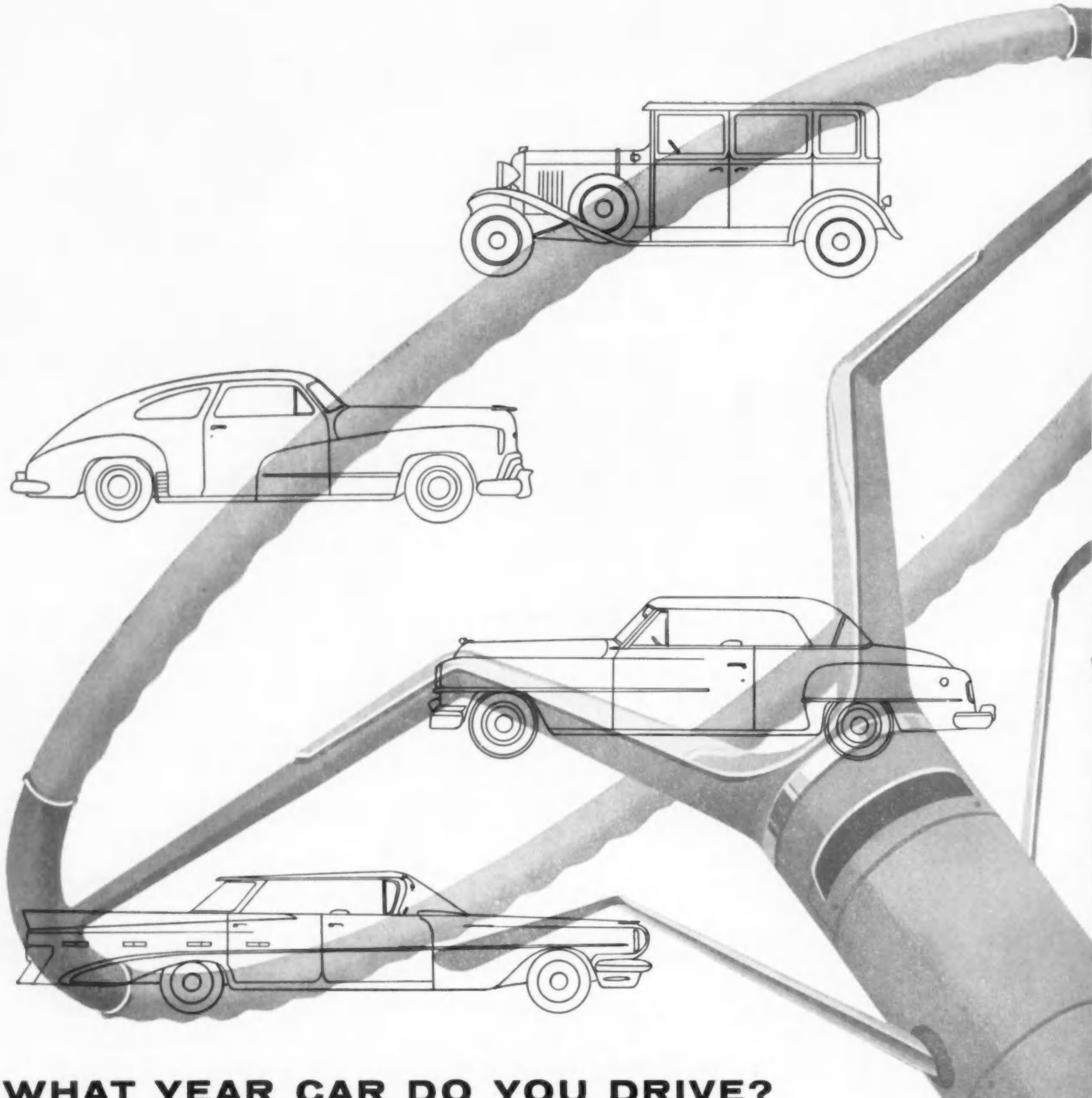

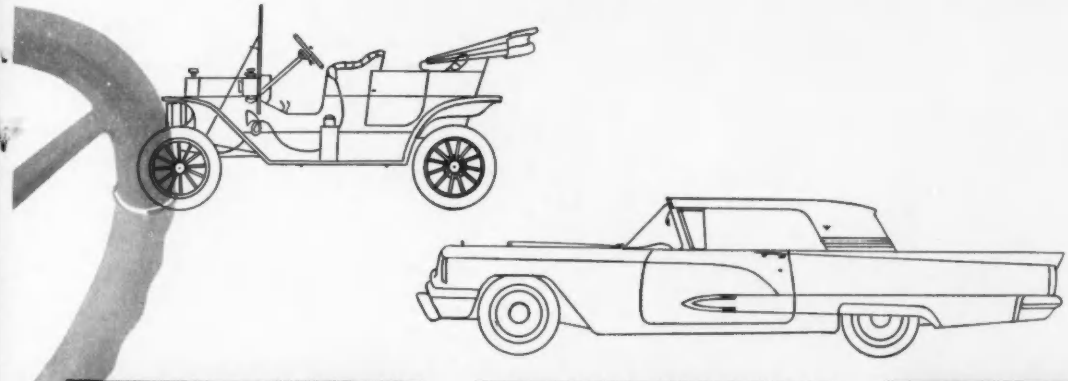

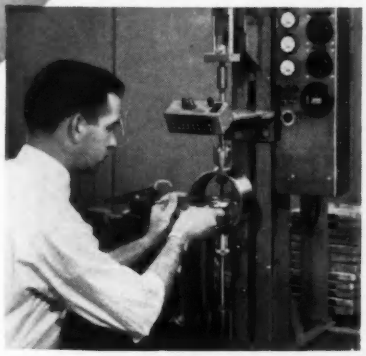

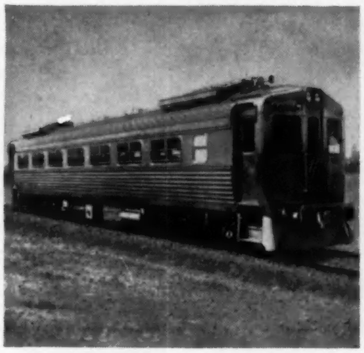

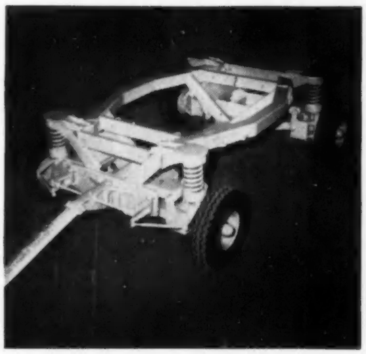

SAE journal

For Sake of Argument

Take Your Pick . . .

"Personal emotions and the background of personal life can't be separated from one's business performance and attitudes."

Proponents of two opposed theories agreed on this single point the other night. But they remained 180 deg apart on what actions follow logically from that premise.

One administrator reasons: "The supervisor must therefore think first of his personnel as people. He should aim *first* to make them happy as individuals . . . move them to business objectives as directly as possible within the limits of their happiness as individuals."

The other feels the business objective should take precedence. "The supervisor," he reasons, "should first clarify his objective and what seems the best way to get to it. Next, he should consider carefully the human elements involved in getting there. *Then*, make everybody as happy as possible within the limits of the predetermined business objective.

"Researchers at Lockheed," he points out, "found out some years ago that morale levels were better among women who thought a boss a good administrator but didn't like him, than among those who did like him and had no complaint to make about him." (Good administration was defined as "equitable and uniform application of company policies.")

Rounding the circle, both supervisors ended by finding one other point on which to agree: If people can't seem to do *anything* to suit you, the trouble is probably in you.

Norman G. Shidle

FROM NEW YORK: "All four of my brakes are always perfectly adjusted whether I'm on the throughway or driving in bumper-to-bumper traffic in the city."

FROM DENVER: "There's new pleasure in mountain driving now that I know my brakes always have maximum stopping power."

FROM ATLANTA: "Knowing our brakes are never out of adjustment gives me a wonderful safe feeling. I'm at ease even when taking the children to school."

FROM MINNEAPOLIS: "In all kinds of weather, self-adjusting brakes give me stopping power at its best—and save the cost of brake adjustments."

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Bendix* Self-Adjusting Brakes give dealers a double-barreled sales appeal: safety plus economy. And those in close touch with today's market know that these two appeals—safety and economy—are among the most powerful sales points that can be made to the American buying public.

Car prospects quickly realize that there's real safety in always maintaining the brakes at maximum stopping power. And the obvious savings that they make by eliminating the expense and bother of periodic brake adjustments. What's more, with all brake shoes always correctly adjusted, there's always the right clearance between pedal and floor. And that's a feeling any car buyer appreciates.

Reasons like these make self-adjusting brakes a good "talking piece" for dealers. It won't be long before car buyers everywhere will know about self-adjusting brakes—and want them. But this latest advancement in brakes joins power brakes and power steering as examples of how Bendix pioneers and develops improvements to meet the needs of the automobile industry.

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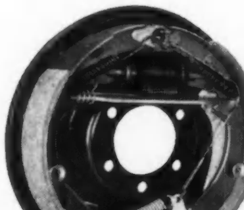

When shoe clearance exceeds a predetermined amount, a ratchet sets up the star wheel adjuster one notch—as the brakes are applied when the car is in reverse. This automatically adjusts the shoes to exactly the right fit within the drum and compensates for lining wear.

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chips

from SAE meetings, members, and committees

130,000,000 HP WOULD HAVE TO BE DEVELOPED by a nuclear rocket to transport a 500,000-lb interplanetary vehicle from the earth's surface to a 300-mile orbit, according to NASA's Frank E. Rom and Paul G. Johnson. Reactors operating at such power levels are several orders of magnitude beyond current practice. On the other hand, only 130,000 hp is needed to give an acceleration of $10^{-2}g$ — sufficient for space missions — to a vehicle with a 500,000-lb initial weight, once it is in the 300-mile orbit. Thus, the authors say early space missions utilizing nuclear propulsion will have to be accomplished in two stages: (1) a chemical booster rocket to get the vehicle into orbit; (2) a nuclear rocket system to take over from there and carry out the space mission.

DRIVERS very much enjoy their small cars, but big ones will always have a host of friends. They are called passengers.

A ROCKET SLED RIDING ON MOLTEN METAL (shown at right) is being used to test new airfoils, pilot ejection seats, and a unique rocket nose cone. As the sled — a design of the Hunter-Bristol Division of Thiokol Chemical Corp., hits speeds greater than that of sound, the surface of its specially designed runners liquefy to smooth-flowing molten metal.

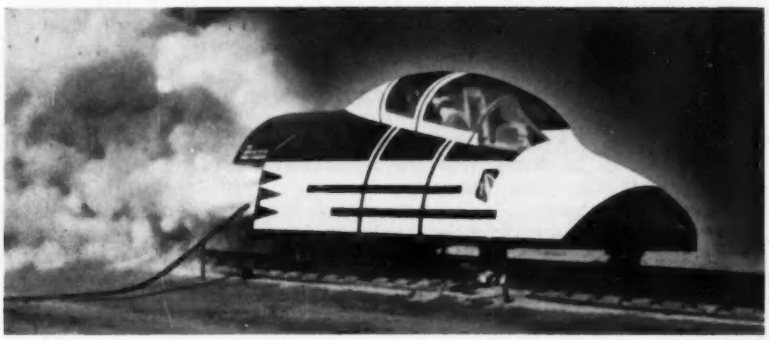
CHALLENGES TO MAN'S USEFULNESS have probably never been more serious than during this decade of the technological breakthrough into space. At a recent serious symposium, a panel of experts was considering the utility of man in the space age. It was politely suggested that a book on the subject had already been written: "Where Did You Go? Out! What Did You Do? Nothing!"

Do something you are proud of — and you won't have to try so hard to be proud of what you do.

ON QUIET DIFFERENTIALS — Consider the case of the irate automobile owner, who, after complaining to the service manager, admitted that maybe his demand for a quieter differential was out of line, but did ask the gentleman to take one more ride in his new car. The manager agreed. Whereupon the owner drove the manager to his home, picked up the family dog, and proceeded down the street. Upon reaching 30 mph, the speed at which the objectionable noise occurred, the dog began to howl. At this point the owner turned to the service manager and said, "Now Sir, you've convinced me that the axle noise is normal, will you please convince my dog."

IN AN ITALIAN CUSTOM BODY shop, there is said to be a wall motto which reads: "Weight is the enemy; wind resistance is the obstacle."

A few of the parameters indicated by this advice are interesting, says Consumers Union's Laurence E. Crooks. In CU's simulated traffic test, the highest mileage so far has been from the 1335-lb Renault 4CV, at 33 mpg. (The average of current Ford-Chevrolet-Plymouth V-8s on this test is 13 mpg.) As for wind resistance being overcome (and friction too), the highest mileage recorded by these tests at a constant 60 mph was by a 2-passenger, 1.5-liter 1954 Porsche coupe . . . 38 mpg.



The interval that elapses between the birth of an idea and its practical application today is far shorter than in the past.

For instance, 75 years passed between the first meaningful experiments with electricity — by Faraday, Hertz, Ohm, and the others — and the practical use of electricity. But nuclear fission was discovered in 1939 . . . six years later the bomb dropped on Japan . . . and less than 13 years after that the Shippingport atomic power-plant was in service.

Until 1820, when the calculating machine was invented, the abacus was the fastest adding machine in the world — and it had been around for many centuries. Not until 1892 did William Burroughs develop the first marketable adding machine. Not until 1939 was the first large automatic sequenced calculator developed. In 1954, only 15 years later, a machine could add 500,000 numbers per minute and store 40,000 digits.

To get an understanding of the surge of technological progress of our time, consider the accomplishments of man in relation to the time he has lived here on earth. Man, as we know him, has been living for 50,000 years on this minor planet in the rather unimportant galaxy which we call the Milky Way.

Since 50,000 years is hard to conceive, let's condense the time scale to 50 years.

50 years ago, modern man first trod the earth.

10 years ago, he stopped living in caves.

5 years ago, he invented picture writing.

2 years ago, Christ was born.

5 months ago, the printing press was invented.

10 days ago, electricity was discovered.

Yesterday, the first plane was flown.

Television was invented **fifteen minutes ago.**

The first jet plane flew **three minutes ago.**

Satellites have been placed in orbit **within the last thirty seconds.**

You will note that everything that makes up the material world as we know it was invented within the last few days.

★

SPACE ERA COMPUTERS

Excerpts from paper by

A. C. Monteith

Westinghouse Electric Corp.

Abridgment of an **SAE Baltimore Section Paper**

IN computer design and control engineering, we are only at the first page of a long history of accomplishment. We have only got started toward what will eventually be done with these machines and techniques in the space era.

Consider the techniques of using numbers — expressed as holes punched in cards or tapes — to control multiple motions of a machine tool. The techniques for getting into tool paths from two-dimensional shapes on drawings have been quite well worked out. More than a hundred such contour milling machines are now either in use or under construction. . . . However, tool programming techniques for the complex three-dimensional paths are now getting under way. Ideas are developing for getting directly from the desired shape to a tool path program, bypassing the conventional engineering drawing. It appears that the rules for fillets and curvatures which the draftsman develops from the basic requirements and dimensions into a finished object may very well be programmed for a computer. This, of course, is a development for the space age.

Computer programs for carrying out a complete order handling procedure are now under way in various stages in some of our plants.

When a specific order enters the plant, the computer performs the order interpretation, the price and delivery checking, the engineering design, and the preparation of manufacturing information (including tools, routing, time values, schedule, and bill of materials). It dovetails with the inventory programs, ordering from stock those parts which are stocked and writes complete manufacturing information for those which are not. It turns out cost accounting and material requirements information for that particular order. It initiates all the paperwork necessary for storerooms and inspection stations so that material flow is maintained from raw materials through work-in-progress inventory to

• We've only started to do what eventually will be done . . . . and your space-age computer will never dance in with stars in its eyes to announce it is having a baby and will be leaving next month.

WILL OUTMODE TODAY'S

finished parts and shipments on order. It supplies all the shipping, invoicing, and accounting papers required for the order. . . . *And, best of all, it does not dance into your office on your busiest morning with stars in its eyes to announce that it is going to have a baby and will be leaving next month . . . At least — not so far.*

The pattern of development is quite clear. For any kind of work whose logic can be preplanned, the workers will no longer have to make the interpretation personally on each order as it flows through a plant. Instead, they will be elevated to the position of designing and developing the computer programs which use this logic on the individual elements of work as they occur. This applies whether it be engineering, writing manufacturing information, determining production schedules, making shipping plans, or cost accounting.

This type of program, of course, will be extended into the less conventional and less repetitive types of products from the knowledge gained in these early applications. It doesn't require much imagination to picture a closing link between this flow of paperwork and the machinery. This will be done in those many cases where the computer can feed out directions for a machine to perform the job — and can do it just as well as men are doing now. The digitally controlled machine tools are, in fact, a first step in this direction.

From all this, we can see that our present exploitation of computer techniques is still in the embryonic stage. Computing power measured by the speed, size of fast memory, power of command, flexibility, and reliability has been increasing at a ratio of ten-to-one; and there is every reason to believe that the increase will continue at least at this rate. Some computers may well be less than pocket size, with the packing density of the human brain. We can see, in short, that space age automation will not be hampered by any ceiling on the advance of computer technology.

Technological change of this sort has changed the nature of engineering. It has increased the cost of engineering content in a given piece of equipment. It has vastly increased the amount of coordinated equipment engineering. And it has changed the educational demands on the engineer.

In systems control engineering, as late as 1945, the demand was for individual controls, each under the supervision of an individual operator. The controls were simple. Their assembly was chiefly a mechanical problem. Coordination and programming were done by human operators. Circuitry was conventionally simple.

By 1952, a change had been felt. The coordinated control system was becoming more commonplace in an effort to lower increasing labor costs of operating mills. The basic control problem was an analytical one instead of mechanical. Sequencing was still done by relays. Regulation was more precise. Magamps and electronics were being used more frequently. Coordination was done by the control system. Programming was still done by human operators. Circuitry was getting more complicated and was "customized."

Now, in 1959, the full impact of the new technology is being felt. The control itself is far different. It has become an all-encompassing analytical problem. Sequencing is done by static devices. Regulation is being done with Magamps and transistors as components. Programming is being done by systems control. The controls, more than they ever were before, are custom built.

What the next major change will be, and when it will come, is not known. What is known is that the

SPACE ERA COMPUTERS

... continued

next major change will result in a completely automated process or factory. This will demand an industrial calculator programmer. And after the first complete automated factory will come a new and still better way of automating a complete factory.

These things are happening in the control field because industry is demanding them. Process speeds are going higher and flexibility of equipment is getting wider. Ten years ago, most process regulators had an accuracy of plus-or-minus two per cent. Today, plus-or-minus two-tenths of one per cent is not uncommon. In another decade it will probably be plus-or-minus two-hundredths of one per cent.

In 1945, a systems control engineer had to be an expert on two things: rotating equipment and electromagnetic devices. In 1959 he possesses, if not a complete mastery, at least an application acquaintance with numerous new and complex design areas, including use of static devices, electronics, semiconductors, servo-mechanisms, and computers. He must thoroughly understand the customer products, machines, and the coordination and programming of those machines which comprise a system. He is concerned not only with his own education, but with the education of the field service engineer and the customer as well.

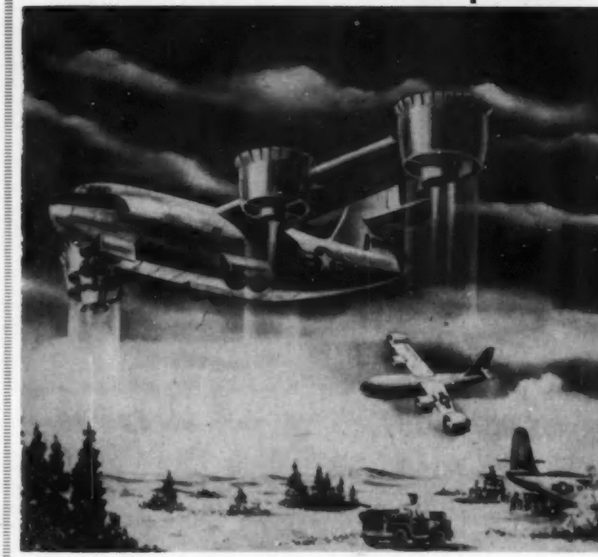
To me, this diversification of responsibility means that we in industry must look for young men with a broad technical training rather than for specialists who know only their own fields. The student who seeks a career in the mechanical and electrical engineering of today must have a basic classical engineering education. To our educators this means a broader base of engineering studies in our colleges. Engineering in the space age begins very much like engineering in any age — with mastery of the fundamentals of the profession.

Engineering in our time undoubtedly wears a glamorous wreath. It is fashioned from newspaper headlines and often colored by the competitive stimulus of the cold war. The truth is: modern engineering doesn't move from Cloud 7 to Cloud 9 in a space helmet.

Before the headline which heralds some outstanding accomplishment, there must be a saturating comprehension of science and engineering fundamentals . . . an ability to integrate one's individual skills with organized effort . . . and an ability and willingness to undertake routine design work.

To Order Paper No. S175 . . .
. . . on which this article is based, turn to page 6.

Airplanes



Ducted Propeller

A Prediction of

Based on paper by
George D. Ray
Bell Aircraft Corp.

TAKE-OFF power to weight ratios of turbine engines will double in the next ten years. VTOL systems producing high-velocity slipstreams will make better use of this improvement than low slipstream velocity systems.

In the VTOL future — a family of bypass engines; improved ducted-propeller powerplants; improvements in augmented and unaugmented turbojets; use of favorable ground effects.

Also, the horizontal attitude aircraft — in which only the thrust direction is varied — will prove to be the best for VTOL.

Current VTOL Powerplants

Right now, the VTOL powerplants that are best suited for the various speed ranges are:

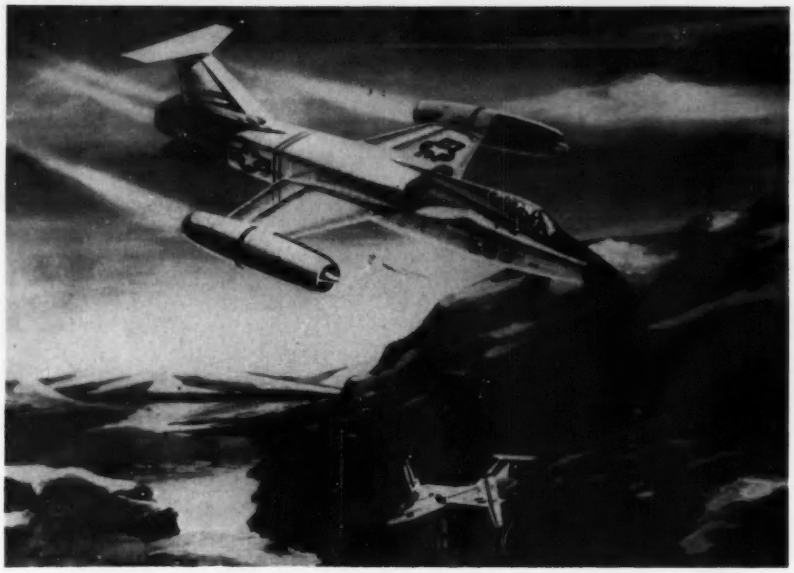
(1) For lower cruising speeds (up to 450 mph) — the ducted propeller.

(2) For intermediate-high subsonic or low supersonic speeds — non-afterburning turbojets.

Turbine Weight Will Be Halved

Turbine engine weight, based on take-off rating, will be halved in the next ten years. We will do this

of the Future



Jet Fighter

Future VTOL's

by operating at higher turbine inlet temperatures, and using variable geometry in the turbine and compressor.

High- versus Low-Velocity Slipstreams

But we won't be able to take full advantage of the weight decrease if we use propulsion systems which produce low slipstream velocities. This is because shaft, gearing, and propellers make up a high proportion of the total powerplant weight. This type of propulsion system is also bulky and heavy. Engines which produce high velocity slipstreams are lighter, and best for cruising, even though there is high fuel consumption while hovering.

Ducted Propellers in the Future

The ducted propeller improves on the bare propeller, which doesn't take full advantage of weight improvements in engines. The ducted propeller is compact, needs less gearing, requires less geometry variation. It can eventually be gas driven, and as the turbine engine becomes lighter, will tend to employ higher disc loadings. At this point it may be hard to distinguish between a ducted propeller and a high-ratio bypass engine.

Coming — A Family of Bypass Engines

A family of bypass engines can be used for all speed ranges. (Lower-speed aircraft will have higher bypass ratios.) The bypass engine can develop higher take-off rating (while maintaining cruising speed economy) by using higher turbine inlet temperature, and geometry variation (fan and turbine).

Other Improvements

Other future possibilities for VTOL include thrust augmenters. Work is being done on the Kappas-Brequet type, where the jet engine exhaust gases are diverted during take-off and landing to drive a fan having a partially admitted tip turbine. This fan is located in the fuselage or along the wing, where it produces thrust by impelling additional cold air downward. Other types of augmenters, having no moving parts, are possible. Improved unaugmented turbojets are also being developed.

Work is being done to obtain favorable ground effects. A jet or fan is exhausted around the edge of a round or delta-shaped wing close to the ground. It is done to produce a pressurized region under the wing. Its value for obtaining lift is still being tested.

Horizontal Attitude Aircraft the Best

The horizontal attitude aircraft, in which only the thrust direction is varied, will be the favored method. Additional fixed-direction engines for lifting only on take-off and landing may be necessary. The difficulty with deflected slipstream, tilt-wing, and tail-sitter aircraft is that excessive controls are needed.

To Order Paper No. S155 . . .
. . . on which this article is based, turn to page 6.

Table 1

Powerglide Thrust Washer Tests

Fluid	Laboratory Tests		Proving Ground Schedules	
	No. of Tests	Success	No. of Tests	Success
A	8	0	10	0
B	4	1	4	2
C	8	5	5	4
D	8	7	6	5

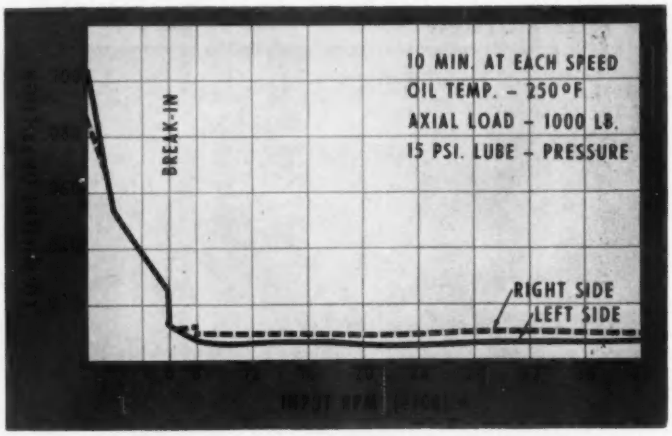


Fig. 1 — Accurate measurement of friction coeffients is obtained on a thrust washer test fixture.

Automatic Transmission Testing

becomes essential for designers

Based on paper by

Howard H. Kehrl, Marvin R. Marsh, and Raymond A. Gallant

Chevrolet Motor Division, General Motors Corp.

AUTOMATIC transmission design can be based on more known quantities and fewer unknowns if laboratory testing is used for accurate identification and quantitative measurement of the magnitude, duration, and effects of transient phenomena.

The laboratory approach is to:

1. Ask the machine what the actual requirements of a new component design should be.
2. Set up test machinery to inflict these requirements on a proposed design and record its performance.

Thrust washer testing

As horsepower has increased, so has the problem of thrust loads imposed by helical gears. A typical thrust washer test fixture places the Powerglide input sun gear in its normal environment so that the effects of lubrication, oil grooves, fluids, materials, and designs may be studied.

Test conditions are determined by plotting a load-speed curve from the torque converter absorption curve. These values are verified by means of a strain gage transducer in the transmission to determine the presence and magnitude of any transient loads.

With these values, axial load is applied through a hydraulic cylinder. The input sun gear is driven at various speeds up to 4500 rpm. Friction torque of the washer is measured by a spring scale through a lever arm. Lube oil from an external pumping unit is temperature controlled and filtered.

The fixture provides accurate measurement of friction coefficients, as indicated by the curves in Fig. 1. It is interesting to note that the coefficient of friction of the washer is approximately 0.01 as compared with normal dynamic coefficients of friction elements of 0.09–0.15. Apparently, the difference between a thrust washer and a friction element can be only one decimal point.

Table 1 summarizes the effects various oils had on the durability of transmission thrust washers. Close correlation is evident between the results obtained from proving ground schedules and laboratory tests.

Torsional strength of converter shafts and elements

Strength and fatigue life of shafts and converters are evaluated on the basis of engine torque loadings

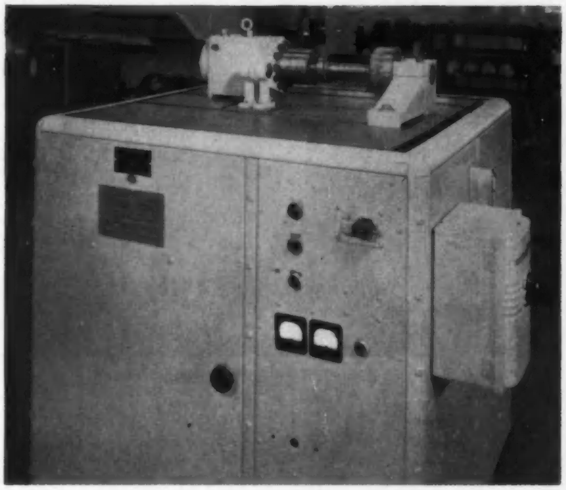


Fig. 2 — Turboglide T_2 shaft mounted in fatigue testing machine of controlled-load type.

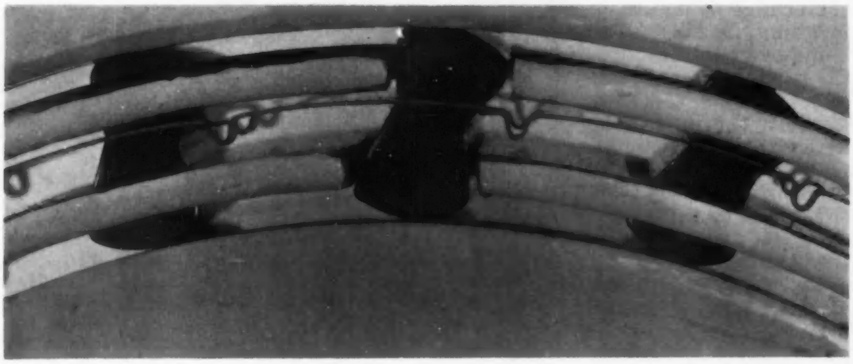


Fig. 3 — Fatigue life of overrunning clutch elements, such as the sprag type shown here, is determined in a stroking fixture completely automatic in operation.

and transient loads induced by severe vehicle operation. Accurate determination of transient values is entirely dependent upon modern dynamic recording.

Fig. 2 shows the Turboglide T_2 shaft mounted in a fatigue testing machine of the controlled load type. The splined drum on the right normally carries reverse clutch plates. In this test, the drum is grounded. Input torque is applied to the splined shaft on the left, which normally carries the T_2 turbine. The equipment shuts down automatically in the event of shaft failure.

The strength of die cast turbines is established by stresscoat, strain-gage measurements, and torsional fatigue tests. Because turbine loads are applied through a large number of blades, care must be exercised in securing the test part to the fixture to assure proper load distribution.

Overrunning clutch testing — static

The overrunning clutch shown in Fig. 3 is part of the geared converter arrangement of the Turboglide. Its function is to permit a particular element to freewheel when it is no longer contributing to converter output. This eliminates the drag and loss of efficiency that would otherwise occur. Its assignment in the transmission calls for high torque capacity in a small space.

A stroking fixture is used to determine the fatigue life of overrunning clutch elements, such as the sprag type used in the Turboglide, or the cam and roller clutches used under the stators of both the Turboglide and the Powerglide. The operation is completely automatic, provides for repeated application of a predetermined torque, as well as rotation to establish new sprag-to-race contact points on each cycle.

Load is applied by an air cylinder through a torque arm, where it is monitored by strain gages and recorded on an oscillograph. Apply load is limited by the known static breakaway capacity of two double-wrap transmission bands attached to the outer race. The resulting rotation prevents

Continued on next page

Automatic Transmission Testing

... continued

Brinelling of the races due to repeated application in a fixed position.

Overrunning clutch testing — dynamic

In the Turboglide neutral to drive shift, the T_1 sprag clutch must accept the sudden change from a high-speed overrunning condition to a high-torque lockup. The T_2 sprag has a similar assignment when the change is made from road load to full-throttle acceleration in the midspeed range.

Machinery was specifically developed to duplicate either of these conditions by providing: high-speed rotation of the inner race; predetermined input torque to the outer race; the means of grounding the inner race; and a measure of the reaction torque.

Testing is done on a single clutch, either the T_2 outer or T_1 inner sprag assembly. In either case the test piece is measured for strut angles, race diameters, and drag torque before entering the test machine.

The cycle begins with the outer race being driven through a reduction unit at 7 rpm (Fig. 4). The inner race is driven in the same overrun direction. When it reaches 3000 rpm, the driving motor is de-energized. A timer then engages a clutch (actually a Powerglide clutch pack) between the inner race and a torque arm attached to a hydraulic cylinder. The rapid torque buildup on the sprags due to the abrupt lockup is limited to a specified value by a relief valve in the cylinder. Movement of the torque arm then trips a microswitch to disengage the clutch, and the cycle is automatically repeated.

An interesting problem in the design of this fixture was the repeated failure of the belt that brings the inner race up to speed. Failure was caused by the decelerating torque of the Powerglide clutch, and was eliminated by installing a small slip clutch between the pulley and the race to limit belt tension.

Wear characteristics are also evaluated by a simple high-speed overrun test.

Converter testing

In converter work, small changes in labyrinth seals, blade angles, and spoke designs exhibit nonlinear effects on converter performance and efficiency. Evaluation of these effects necessitates a high degree of accuracy in the measurement of input and output speed and torque.

A test converter is mounted in a fixture designed to simulate the "in car" condition (Fig. 5), and connected between two 250-hp dynamometers through rubber-bushed propeller shafts. Direct current input and eddy current absorption dynamometers measure torque. The corresponding speeds are measured by digital counters. Frequent calibration of the dynamometers ensures the necessary accuracy.

To minimize the influence of oil temperature on indicated performance, converter outlet oil temperature is controlled within plus or minus 2 F. The heat generated at the lower speed ratios necessitates a 25-gpm oil supply and a large heat exchanger, which is located in the equipment room. Converter charging pressure is held constant by automatic controls.

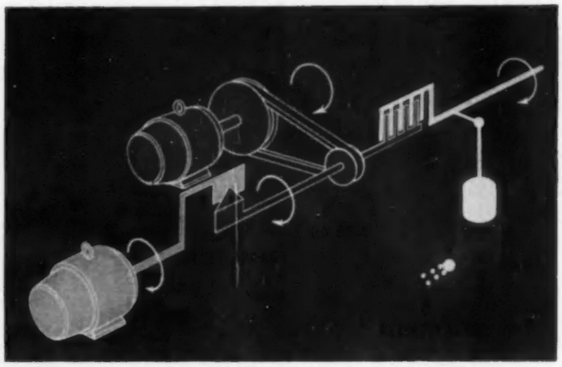


Fig. 4 — Schematic of dynamic test for overrunning clutch.

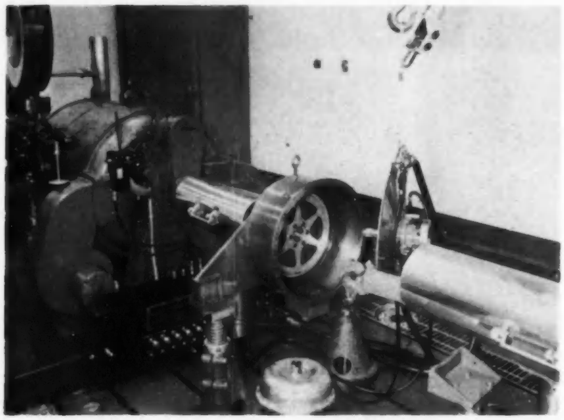


Fig. 5 — Converter testing is accomplished by mounting the converter in a fixture designed to simulate "in car" condition, and connecting it between two 250-hp dynamometers through rubber-bushed propeller shafts.

Provisions are made for measurement of ballooning of the converter hub and flywheel at each output shaft speed. A light flat plate attached to the hub permits measurement by manual operation of a depth micrometer. Since the converter flywheel design does not lend itself to this simpler method, an electronic micrometer is used.

In Turboglide converter work, accurate measurement of the torque distribution between the three turbines throughout the operating range is essential to the evaluation of the effects on performance of small changes in design. This same base equipment is used to make both steady-state and dynamic measurements of these quantities.

Fig. 6 shows the relative torque fixture designed for this use. The gear set is actually part of the fixture, which includes reaction arms for the T_1 and T_2 gear sets and the stator support shaft. The output shaft is connected to the dynamometer.

Constant input torque is supplied by a direct current dynamometer. At each output speed, gear reaction torque is determined by the lever arm and the load on a precision platform scale. A single

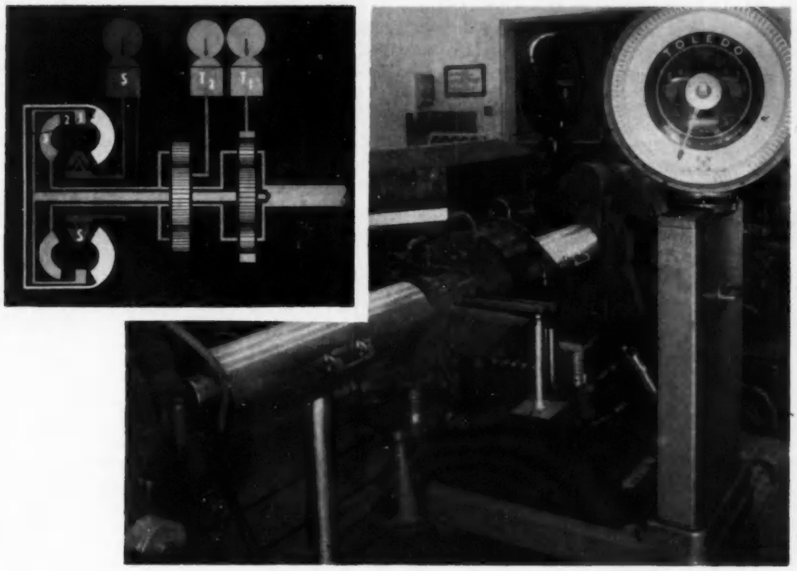


Fig. 6 — Fixture to measure torque distribution between three turbines throughout operating range for evaluating effects of small design changes on performance.

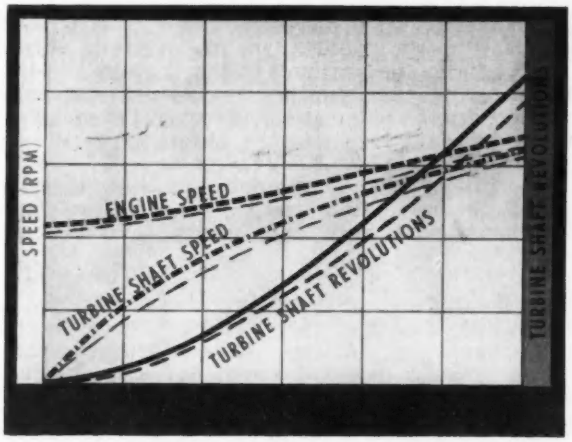


Fig. 7 — Curves show how closely laboratory results correspond with car measurements.

scale is used, reactions being measured one at a time at each speed, while the other arms are simply grounded to the case. Readings are readily convertible to individual turbine torque contributions.

Dynamic measurements can be made with this setup simply by attaching strain gages to grounded lever arms and feeding the results to a multichannel oscillograph.

The usual method of converter performance testing at constant input torque and a series of output speeds produces data which can be converted into car performance after lengthy calculation. Recently this equipment was used to compare vehicle performance of two converters by direct measurement of full-throttle acceleration characteristics.

An engine was substituted for the input dynamometer, and inertia weights for car inertia. With the converter output shaft held by a manually controlled brake, the engine throttle was adjusted to give the desired input torque. The brake was then released, and the converter input and output shaft speed and revolutions recorded against time on an oscillograph. The information obtained (Fig. 7) corresponded closely with car measurements.

Hydraulic test facilities

Basic equipment in a transmission laboratory must include the means for evaluating pump and valve body performance, and parasitic losses.

Pumps are tested on a 15-hp dynamometer. The transmission is reworked to permit the normal pumping operation through suction and discharge passages. Oil pressure is controlled, and flow is measured by a positive displacement meter. A separate temperature controlled pumping unit supplies oil to an open sump beneath the transmission, where a constant level and temperature are maintained.

Pump performance is gaged by measuring flow, pressure, input torque and speed, and vacuum at the suction side of the pump. Any restriction in either the suction or pressure passages which affects pump delivery or horsepower requirements is readily isolated. The equipment is also used to measure parasitic loss. Measurements are made of input torque and speed. From this the horsepower required to drive the transmission at various speeds is plotted.

Another test fixture of great value is a spin rig. This piece of equipment permits variable-speed input to the transmission and convenient measurement of associated pressures and input speed.

To Order Paper No. 30R . . .
. . . on which this article is based, turn to page 6.

High energy rate shapes materials

Based on paper by

J. B. Ottestad

General Dynamics Corp.

HIGH ENERGY RATE PLASTIC DEFORMATION represents a new technique for fabricating materials. Utilizing high unit pressures applied at high speed, the new process appears to solve many of the common problems experienced with material forming — oxidation, scale growth, heat transfer, deformation limits, producible pressures, tooling costs, and equipment size. Although still in the development stage, the process already has produced a number of noteworthy accomplishments. And future feats are expected to be electrifying — such as the production of a whole new family of materials with strength-to-weight ratios 2–10 times that now used.

The reshaping of any body of metal requires energy, not just the application of force. Force must be applied against the material and sustained over a finite stroke to accomplish the reshaping, hence, the term energy. If the moving of the metal is done in some measured time, an energy rate can be developed. Thus, high energy rate denotes not only the delivery of high magnitude forces to the workpiece but also work done in a very short time.

Reduction of time immediately provides an answer to the problems of scale growth, oxidation of material, and heat transfer. Since each of these problem areas is dependent on time, reducing time to a minimum also reduces their effects.

Working metals in a very short time means also that the velocity with which the metal is being moved is very high. Most metals can be stretched much further when moved rapidly than if moved slowly. In other words, dynamic stressing allows much greater apparent unit strains than does static stressing. To the producer of hardware this means deeper draws, elimination of several annealing steps, fewer staging operations in forging or rolling, and the producibility of more complex parts.

Determining the behavior of metals under load has, in the past, been a trial and error process. Development work with high energy rate forming

The plastic deformation process

reshapes a given quantity of material from a simple billet into a final, complicated, desired shape while minimizing waste material and preserving the inherent physical strength of the metal. This process is used in: forging, extruding, rolling, swaging, and sheet forming. However, usually these techniques are only the first step in the fabrication of a final part wherein extensive post machining and treating operations are required to produce the final product.

Plastically working metals at temperatures below their natural melting point refines the grain and flow lines to greatly increase the metals' strength. At the lower temperatures, however, there are limitations to the amount the material can be deformed without cracking. Further, with reduction in temperature the yield strength of the material increases causing an increase in the total force necessary to cause the metal to flow.

To minimize the power required to form a given part and to obtain maximum deformation, the material is heated as high as is possible and still preserve its physical strength. At these temperatures two other problems arise, scale generation or oxidation of the material and heat transfer from the material to the tooling.

During the working of metals, scale is driven into the finished part severely limiting the surface finish and tolerances obtainable. Heat generation in the tooling reduces its service life and pressure holding capacity.

Even under high temperature conditions the majority of metals require high unit pressures to cause them to flow into or through dies. As individual components increase in size the requirements of total force and energy increase correspondingly. With current techniques the sizes of equipment to develop the forces needed for today's parts are huge and for tomorrow's parts would be overwhelming.

The process of plastically deforming metal is the core of the fabricating industry. While it is desirable to improve the process from the standpoint of the cost of today's products, it is mandatory when considering even the producibility of tomorrow's products. The need for working tougher materials to closer tolerances, more complex shapes, greater size, is already beyond present capabilities. Thus the problems of material oxidation, scale growth, heat transfer, deformation limits, producible pressures, tooling costs, and equipment size must be solved. High Energy Plastic Deformation of Materials, a new process described in this article, may provide the answer to these problems.

shows that with high unit pressures applied at high velocities metals can be considered to flow like fluids. This means that hydrodynamic equations can be written that indicate the exact behavior of the metal being worked. Thus, extremely high pressures on the material can be not only produced but accurately predicted.

High unit pressures pose die and tooling problems. Once again high energy rate offers a possible solution. With slow operations the tooling must withstand high unit pressures slowly applied and sustained. With dynamic loading the die can withstand extremely high pressures due to the combination of static strength and the natural inertia of its mass. For example, a lead bullet cannot be pushed through a steel plate but it can be shot through that same plate. Thus, tooling used with a high energy rate can withstand much higher pressures even though they may be much smaller than those used in today's equipment.

The final problems of size, weight, and complexity of current equipment are particularly vulnerable when considering high energy equipment. Present equipment must be able to generate high forces and must provide a means for reacting against these forces. In high energy rate equipment the generation of high forces for a short time interval can and has been accomplished by a variety of means. Containing these forces in the power unit lends itself to the dynamic loading principle for tooling. The reaction system also is solved dynamically. Instead of the usual stiff structure rigidly mounted on a massive foundation, the equipment is floated with respect to the ground.

Reaction of tons of force is accomplished by simple inertia masses moving at some velocity in a direction opposite to the driving force. Thus, high energy rate applied to the plastic deformation process holds promise of answering the major problems facing industry.

State of the Art

A variety of energy sources for this process have been tested and are in various stages of development. These include explosives, compressed gas, high energy spark, burning gases, liquid propellants, and collapsing high density magnetic fields. With these sources, energy levels of several million foot pounds have been generated in equipment weighing only a few thousand pounds. Floating reaction systems have been successfully tested wherein a simple plate weighing only a few hundred pounds has reacted forces in excess of 2500 tons for a time duration of several milliseconds.

Actual accomplishments to date include:

1. Extrusions of tungsten at 4000 F where standard tool steel dies have withstood, with no appreciable wear, several shots with ratios of billet area-to-finished part area over 40/1.

2. Forgings of aluminum, chrome steel alloys, and stainless steel have been made with zero draft angles, tolerances to 0.001 in. on parts 3 in. in diameter, and surface finishes of less than 18 microin. per in. In some forgings, standing stiffners 1 in. high and only 0.050 in. thick have been made in a 1 in. by 1 in. waffle pattern on plate 3/16 in. thick.

3. Domes and cones 4 ft in diameter have been formed in 1/16 in. to 1 in. plate using total equipment weighing 1500 lb. Die material was epoxy resin. In several tests precision forming of 17-7ph stainless steel was accomplished using rubber dies.

4. Precision sheets ¼ in. thick of high alloy steel were made in rectangles 30 in. wide and 60 in. long from a billet 10 in. long, 10 in. wide, and 4.5 in. thick in 0.003 sec by means of sheet explosive and a simple surface table.

5. Coextrusion of bimaterials wherein one material forms the core and another the exterior have been made using steel and aluminum, tungsten and chromium, and aluminum and water. The advantages here lie in the ability to produce a precision part with a tough interior and an oxidation-resistant exterior or, in the latter case, an aluminum tube ¼ in. in diameter with a 0.002 in. hole the full length.

Other case histories include 0.010 in. fins on steel and copper extrusions, and the forging of precision gears in one blow. The evidence shows that more complicated parts can be realized with cheaper dies of longer life from high energy rate applications.

Future Processes

Precision forgings of exotic materials with tolerances of 0.0001 in. and glass-like surface finishes will be producible in sizes several feet square. This will be done using disposable dies of plastic for an inexpensive prototype and light plastic dies with sprayed-on hardened faces for production units. The machine capable of this operation will be light enough to be portable, will be operated by one man, and will cost only a few cents per part to operate.

Extrusion castings will be produced wherein material heated well below its melting point will literally be squirted into a complex die to make in one piece a component that now is assembled from several hundred individual parts. This component's strength and service life will be several times greater and its cost a fraction of its present-day counterpart. Major skin assemblies will be forged into shape with integral stiffners to eliminate subframe problems.

Steel and nonferrous extrusions will be available in tubing and structural shapes wherein web thickness could be only a few thousandths of an inch. Further, these sections would be available with oxidation-resistant coatings of aluminum, nickel, and chromium. Plate will be made with precision thickness measured to within 0.001 in. These will be produced not on the massive rolling mills of today but rather on simple installations consisting of an energy source and an inertia surface flat. The energy source will create an artificial gravitational field on the billet equal to 300,000 times that of the earth's causing the billet to spread like hot butter.

Last but not least a whole new family of materials will be available whose strength-to-weight ratios will be 2 to 10 times that now used. This will come not through an alloying process, but rather through the mechanical working of the metal under tremendous temperature and pressure conditions. Experiments conducted recently indicate that such material can be produced in large enough amounts that within 10 years it will be available for production components.

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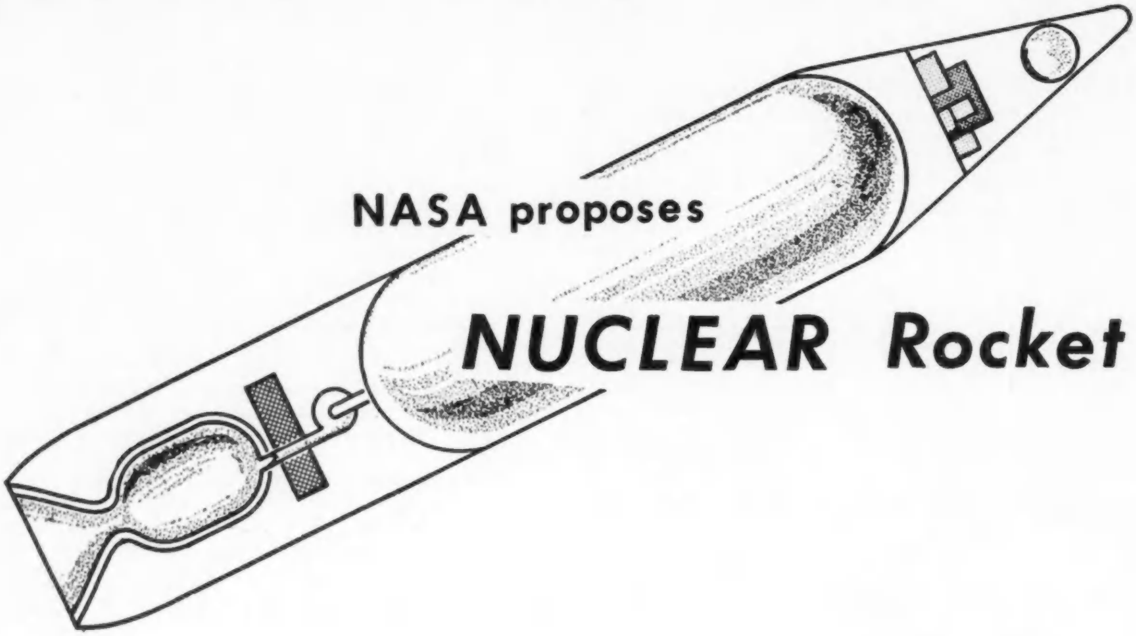


NASA proposes *NUCLEAR* Rocket

The low-power space nuclear rocket conceived by NASA engineers is described here. It is compared with the chemical rocket and the nuclear turboelectric ion propulsion system.

In developing the concept for this low-power rocket, NASA engineers concentrated on attaining low weight and high hydrogen temperature, and on solving problems concerned with automatic control and operation of high-temperature reactors.

It was presumed that the NASA 1.5 million-lb thrust engine would be available, and could place 25,000 lb in orbit, at the time the nuclear rocket is ready for test.

As experience is gained reactors of higher power can be developed. These can, perhaps, be used as second stages of larger chemical boosters. Finally, high-power, high-temperature rockets for booster application can be undertaken.

In addition to describing the low-power nuclear rocket, the complete paper discusses the various types of orbits possible for Earth-Mars trips, the performance possibilities of nuclear rockets, particularly for the low-power rocket described here.

Next month, Victor P. Kovacik and Daniel P. Ross of Thompson Ramo Wooldridge will describe the nuclear turboelectric ion propulsion system in more detail.

Excerpts from paper by

Frank E. Rom and Paul G. Johnson

Lewis Research Center, National Aeronautics & Space Administration

A LOW-POWER space nuclear rocket capable of making an interplanetary flight, once it has been raised to a 300-mile orbit around the earth by a chemical booster, has been conceived from the following point of view:

- **Primary emphasis was on low weight to allow maximum propellant weight and payload.**
- **No emphasis was placed on thrust level, since space missions starting from orbit don't require large thrusts.**
- **Stress was placed on high-temperature operation, so that specific impulse would be as high as possible.**

System description

Reactor — Two principles are important in reduction of reactor weight. First, the total flow-passage volume should be as small as possible so that the reactor will include as much moderator as possible. A flow area equal to 10% of the reactor core frontal area was chosen for this reason. Such a low flow area will make the hydrogen flow rate small. However, since large thrusts are not required for flights starting from orbit, this feature will not greatly penalize the nuclear rocket performance.

The second principle is that the moderator should be chosen on the basis of ability to produce minimum reactor size and to operate at as high a temperature as possible. Of the available moderating materials, beryllium oxide and graphite are the most capable of operating at high temperature. Beryllium oxide can operate at temperatures approaching 4000 F while graphite can operate at temperatures of 5000 F. Beryllium oxide is a much better moderating material than graphite and, therefore, will yield reactors of lighter weight. In addition, beryllium is completely compatible with hydrogen up to temperatures of 4000 F, whereas graphite is not

to Explore Space

compatible with hydrogen unless it is protected by a coating or an inhibitor contained in the hydrogen. It was, therefore, decided to use beryllium oxide as the moderating material for the conceptual design study.

Regarding the attainment of high hydrogen temperature, the materials that contain the fissioning uranium and provide heat-transfer surface to heat the hydrogen must have the highest possible operating temperature and be compatible with both hydrogen and the uranium-bearing compound they contain. Of all the metals, tungsten has the highest melting point, and the highest strength at elevated temperatures, and is compatible with both hydrogen and uranium dioxide. This makes tungsten the best and most obvious choice among metals. The fuel elements, which are defined as the parts of the reactor containing the fissioning uranium and supply heat-transfer surface for heating the hydrogen, are assumed to be made of tungsten containing uranium dioxide. Such a fuel element is expected to be capable of operating at temperatures up to 5000 F. For comparison, the melting point of tungsten is 6100 F.

Tungsten is quite difficult to work because of its high-temperature strength and brittleness. Therefore, the fuel elements should be designed to be as simple as possible from the point of view of fabrication. Flat or slightly curve plates made by powder metallurgy techniques are perhaps the simplest shapes to make.

Another difficulty connected with tungsten is its high neutron capture cross-section, which means it competes with uranium for the neutrons generated in the reactor. Natural tungsten consists of a series of isotopes: 180, 182, 183, 184, and 186. Of these only tungsten-184 has a suitably low capture cross-section. Tungsten-184 can be separated from natural tungsten. It would be a costly process but the savings in uranium over a natural tungsten reactor may pay for the separation of the tungsten isotope.

The reactor concept shown in Fig. 1 was based on these considerations. The reactor is a right circular cylinder 28 in. in diameter and 36 in. long, with fuel elements and moderator arranged in concentric annuli. The fuel elements are arranged in two of the concentric annuli, separated by beryllium oxide moderator regions.

The fuel element design is shown at the right. It consists of a series of slightly curved, uranium dioxide bearing, tungsten-184 plates 0.034 in. thick separated by a 0.048-in. gap. Each plate is about 2 in. long in the flow direction The fuel elements have ears that fit into slots in the two side plates. The total height or thickness of the entire element is 0.458 in. A possible fabrication process consists of a

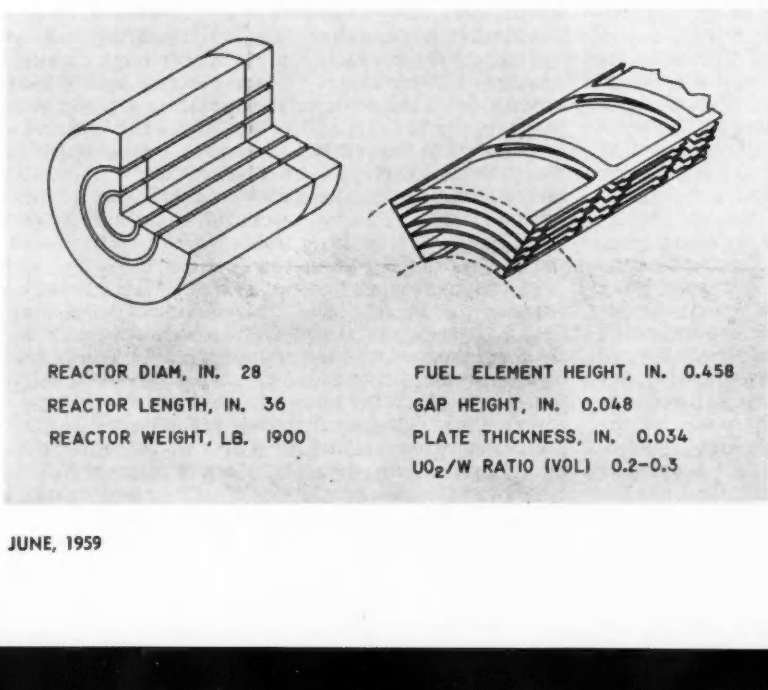


Fig 1 — Space nuclear rocket reactor. Fuel element design is shown at right.

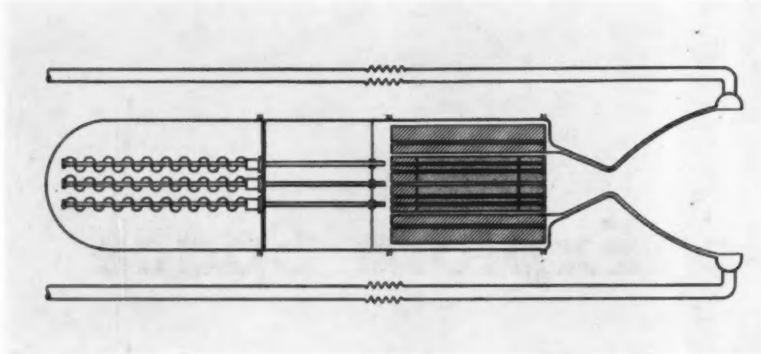
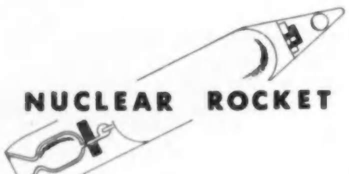


Fig. 2 — Powerplant cross-section. Reactor core and its control-rod structure and drive mechanisms are enclosed in cylindrical pressure shell.



NUCLEAR ROCKET

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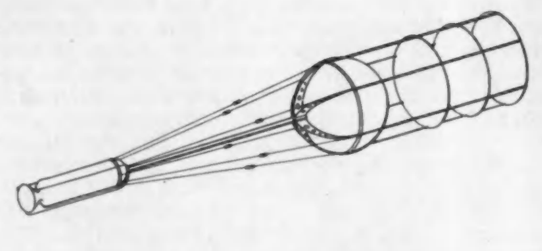
cold pressing of the tungsten-184 and uranium dioxide powders in the ratio of 20% uranium dioxide to 80% tungsten by volume. This would be followed by a hot sintering operation. The proper number of these elements is arranged to complete each annular ring in the reactor.

The moderator is considered to be made of hot pressed blocks of beryllium oxide arranged between the fuel element rings. Cooling of the moderator is provided by the flow of hydrogen in the outer passage of the fuel element. The hydrogen temperature in the outer passages is kept low enough by proper choice of the outer passage height so that the beryllium oxide never exceeds 4000 F.

A 6-in.-thick beryllium reflector, used to reduce the required core size, surrounds the outer fuel annulus. Beryllium metal should be used because its nuclear characteristics are slightly better than those of beryllium oxide and it has a lower density. Its relatively low temperature limit is not prohibitive for use as a reflector since the reflector is cooled by very-low-temperature hydrogen. The reflector at the front end of the reactor is 6-in.-thick beryllium. The rear reflector is 6-in. beryllium oxide since it is at the high-temperature end of the reactor, where it is more difficult to cool. The overall weight of the reactor is 1900 lb.

Powerplant — The reactor core and its control-rod structure and drive mechanisms are enclosed in a cylindrical pressure shell, as shown in Fig. 2. The cooled exhaust nozzle is attached to one end of the pressure shell. Reactor control is provided by a series of neutron absorbing rods distributed uniformly through the moderator regions to provide a minimum of neutron flux distortion. They are operated by small electric motors located on a bulkhead in the pressure vessel. The gamma heating is removed from the control-rod mechanisms by the hydrogen before it flows through the reactor. Electrical power is supplied by solar cells. Hydrogen, pressurized in a storage tank, is supplied to the



TOTAL POWERPLANT WEIGHT, LB	2,400
TANK WEIGHT, LB	700
STRUCTURE WEIGHT, LB	500
PROPELLANT WEIGHT, LB	12,100
PAYLOAD WEIGHT; LB	9,300
TOTAL WEIGHT IN INITIAL ORBIT, LB	25,000

Fig. 3 — Nuclear rocket space vehicle for minimum-energy Mars probe.

powerplant at a pressure of about 35 psia. The liquid first flows through the regeneratively cooled stainless-steel nozzle walls. It then passes through passages in the reflector to remove the heat generated by neutrons and gamma radiation as they pass through the beryllium. At this stage the hydrogen is completely vaporized and is at a temperature of about 200 R. It then is used to cool the control-rod mechanisms and passes into the reactor at a pressure of 25 psia. The hydrogen first cools the forward beryllium reflector, then is heated as it passes over the surfaces of the tungsten fuel elements. At the exit, the hydrogen, heated to 4500 F, is at a total pressure of 10 psia due to accumulated pressure drops. It is ejected through the nozzle with a velocity coefficient of 0.96 to produce thrust. The nozzle has an area ratio of 50/1, which produces a specific impulse of 940 at the hydrogen pressure and temperature. The hydrogen flow rate is 0.35 lb/sec, which produces a thrust of 330 lb. The maximum fuel element temperature is 5000 F, while the maximum moderator temperature is 4000 F. The reactor power

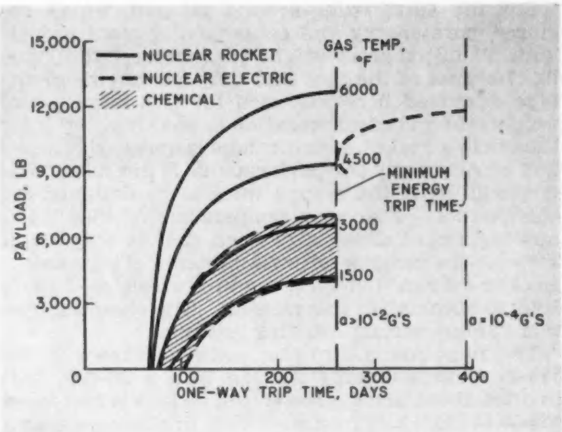


Fig. 4 — Comparison of systems for Mars probe mission. Initial weight in 300-mile orbit: 25,000 lb.

Table 1 — Powerplant Performance Characteristics

Reactor Inlet Hydrogen Pressure, psia	25
Reactor Exit Hydrogen Pressure, psia	10
Reactor Inlet Hydrogen Temperature, F	– 260
Reactor Exit Hydrogen Temperature, F	4500
Maximum Fuel Element Temperature, F	5000
Hydrogen Flow Rate, lb/sec	0.35
Specific Impulse, lb/(lb/sec)	940
Thrust, lb	330
Reactor Power, mw (1 mw = 1300 hp)	6.7
Total Powerplant Weight, lb	2400

is 6.7 megawatts. The additional weight of the control-rod mechanism, nozzle, pressure shell, solar batteries, and guidance systems is assumed to be 500 lb. The total powerplant weight is then 2400 lb. The powerplant performance characteristics are summarized in Table 1.

Vehicle — Fig. 3 shows a nuclear rocket spacecraft using the powerplant described. The total weight of this vehicle on the Earth's surface is 25,000 lb. It is boosted into a 300-mile orbit by a chemical rocket booster. The hydrogen in liquid form is stored in a spherical tank at a pressure of 35 psia. The tank is assumed, for weight calculation purposes, to be constructed of 0.020-in. stainless steel and is pressure stabilized. The thrust forces are transmitted from the engine to the tank by means of the structure shown. The payload and electronic equipment are placed on the tank opposite the powerplant to give the greatest possible protection from the reactor radiations. No shielding is required to protect the liquid hydrogen if the angle subtended by the tank is less than 20 deg, since less than 1% would be evaporated as a result of reactor operation. The shielding required to prevent evaporation would weigh more than the propellant evaporated.

This drawing shows the dimensions of the hydrogen tank for the minimum-energy Mars probe mission. For more difficult missions the payload would shrink and the tank volume would increase to accommodate the larger propellant requirement. For long interplanetary round-trip flights, liquid hydrogen must be stored in the presence of solar radiation. The hydrogen is protected during the coasting phases by means of the three solar radiation reflectors located in front of the tank, as shown. They are very light weight since they are fabricated of thin plastic sheet that has been gold plated. During the coast phase the spacecraft is oriented so that it always points toward the Sun to make the solar radiation shields effective.

Comparison with other systems

Fig. 4 indicates the relative merits of the nuclear rocket system, chemical rockets, and nuclear turboelectric ion propulsion systems. The Mars probe payload is plotted as a function of trip time for the three systems. The nuclear rocket performance is shown for temperatures of 1500, 3000, 4500, and 6000 F. The powerplant used for each operating point illustrated is the one described in this paper (Figs. 1 and 2, Table 1). Actually, the performance could be improved over that shown if the optimum engine size were used for each operating point.

Chemical rocket performance is indicated by a band. The lower edge of the band corresponds to conventional gasoline-oxygen propellants, while the upper edge is for high-energy propellants such as hydrogen-oxygen. The lower conventional chemical rocket performance compares very well with the 1500 F nuclear rocket, while the high-energy chemical rocket compares favorably with the 3000 F nuclear rocket.

The nuclear electric system performance was obtained by using powerplant weights that could be achieved by the use of a nuclear sodium vapor turboelectric ion propulsion machine. The turbine inlet temperature is assumed to be 2000 F. The powerplant weight for this system is assumed to vary from 80 lb/kw at a power level of 10 kw to 27 lb/kw at 100 kw and 15 lb/kw for powers of 1000 kw and greater. The efficiency of converting electrical to kinetic energy in the ion jet is assumed to be 0.67. The ion propulsion engine is operated at a specific impulse of 5000 lb/(lb/sec), which is found to be the best value for an acceleration of 10^{-4} g and the minimum-energy Mars trip.

The nuclear electric system has longer trip times than the nuclear rocket or chemical systems. This is because of the low accelerations or high powerplant weight of the ion propulsion system. The thrust is 10^{-4} times the initial weight, so that a great deal of time is required to get up to speed. If more speed is desired to reduce the coasting portion of the flight, still more propulsion time is required. A point is reached where the savings in coast time are more than offset by the increase in propulsion time and the curve doubles back, as shown. This results in a minimum time for the nuclear electric system of 260 days.

At this trip time the payload of the nuclear rocket

NUCLEAR ROCKET

. . . continued

and nuclear electric systems are about the same. The nuclear rocket has the feature that payload can be sacrificed to shorten trip times. For example, in the case of the 4500 F nuclear rocket, a 50% reduction in payload permits a trip time reduction from 259 to 100 days. If payloads of 2000 lb are all that is necessary, the trip time could be reduced to about 76 days.

The performance of the three propulsion systems for round-trip Mars missions is compared in Table 2. All the missions start from a 300-mile orbit about the Earth. The powerplant for all the nuclear rocket vehicles, except in the case of the 500,000-lb initial weight, is the powerplant described in this article. At 500,000 lb the powerplant is scaled up to produce 35,000 lb of thrust needed for near optimum acceleration. As before, the performance of the nuclear rocket could be improved by optimizing the engine design for each mission and by the use of staging. The nuclear electric powerplant size is chosen to give the best performance when operating at a specific impulse of 5000 lb/(lb/sec) and at an acceleration of 10^{-4} g. Only chemical rockets with a specific impulse of 400 lb/(lb/sec) were considered for comparison on the round trip missions.

For the minimum-energy Mars round trip the initial weight in orbit is 25,000 lb. The nuclear rocket, operating at a temperature of 4500 F, shows a payload about one-half of the nuclear electric system. At 6000 F the nuclear rocket has about 90% of the payload of the electric system. The nuclear electric system, however, has a total trip time that is about 13% greater than the nuclear rocket. The chemical rocket has a payload of only 1800 lb.

For the Mars swing-around mission, which requires more energy and consequently more propellant, the initial gross weight was increased to 100,000 lb. Because of the fact that only one engine of the type described here was used for this large initial weight, the initial acceleration is less than 10^{-2} g for the nuclear rocket, which causes large gravity losses and consequently the performance is not as good as it should be if the engine were to be designed for this mission. Even at a temperature of 6000 F the nuclear rocket shows a payload that is only about 27% of the nuclear electric system. The nuclear electric system, however, requires about 60% more time to accomplish this mission. The chemical system cannot accomplish this mission.

The final round-trip Mars mission shown is the 570-day excess-energy mission with a 30-day wait in orbit about Mars. The initial weight is increased to 500,000 lb. The nuclear rocket in this case uses a scaled-up engine, which weighs 17,000 lb and has a thrust of 35,000 lb. The importance of obtaining high temperature for the more difficult missions can readily be seen in this as well as the previous mission. The nuclear electric system suffers in the case of excess energy missions, which have relatively short waiting times. In order to achieve the waiting time of 30 days in Mars orbit, the time for deceleration and acceleration must be added to the waiting time. It is not possible to accomplish this mission at accelerations less than 2×10^{-4} g. The nuclear-electric system has accelerations less than this, so it cannot do this mission unless the waiting time is increased by at least 780 days. Trajectories for nuclear electric systems have not as yet been thoroughly investigated. There may be trajectories that enable it to accomplish a 570-day trip with a waiting time in orbit at Mars of 30 days. This mission, if it can be accomplished at all with the electric system, would require large amounts of excess energy with consequent reductions in payload.

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Table 2 — Comparison of Systems for Round-Trip Mars Missions [Initial Orbit Altitude, 300 Miles]

	Propulsion System	I, lb/(lb/sec)	Temperature, F	Payload, lb	Total Trip Time, days
Minimum-Energy Mars Round Trip (Initial Weight in Orbit, 25,000 Lb)	Chemical	400	—	1,800	973
	Nuclear rocket	940	4500	5,500	973
	Nuclear rocket	1330	6000	9,300	973
	Nuclear electric	5000	—	10,200	1099
Swing-Around Mars (Initial Weight in Orbit, 100,000 Lb)	Chemical	400	—	0	—
	Nuclear rocket	940	4500	1,100	508
	Nuclear rocket	1330	6000	7,400	508
	Nuclear electric	5000	—	27,800	803
Excess-Energy Mars Round Trip (30 Days at Mars; Initial Weight in Orbit, 500,000 Lb)	Chemical	400	—	0	—
	Nuclear rocket	940	4500	7,500	570
	Nuclear rocket	1300	6000	49,000	570
	Nuclear electric	5000	—	0	—

4 Plusses; 1 Minus = Low Profile Tire

Based on paper by

W. H. Hulswit United States Rubber Co.

THE low profile tire, characteristic of 1959 passenger cars, has four important plus marks to its credit; only one small minus mark.

This year's tire, commonly of 7.50-14 size and mounted on a 5-in. rim, has these advantages:

- It improves car stability.
- It decreases power consumption.
- It improves tread mileage.
- It reduces squeal.

A slightly harder ride is the only price that has to be paid for these added features. . . . and the difference is no more than that due to a 1 lb increase in inflation.

Improved Stability

The improved stability of the modern tire is easily demonstrated on the road or in the laboratory. Fig. 1, for example, compares the cornering force developed by an 8.00-15 tire and its replacement 15 × 8.6 low profile tire. The low profile tire is shown to develop about 30% more cornering force. . . . And Fig. 2 shows that on static test the lateral stiffness is improved. Fig. 3 compares the self-aligning torque of these tires. Nor is decrease of the cord angle the whole reason for this improvement in cornering force. A change in cord angle from 38 deg to 34 deg would yield only a 10% increase in cornering force, whereas the low profile tire shows a 30% increase on the same test.

Decreased Power Consumption

At normal highway speeds, the low profile tire consumes about 10% less power than its conventional predecessor. At higher speeds, the difference is more pronounced. It gets up to 20% at 100 mph.

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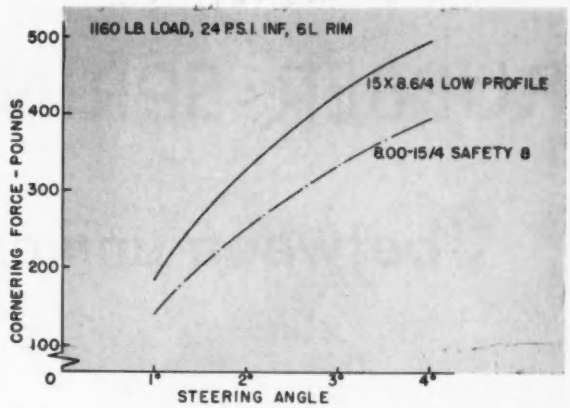

Fig. 1 — Low profile tire, used on 1959 cars, develops about 30% more cornering force than its previously conventional counterpart.

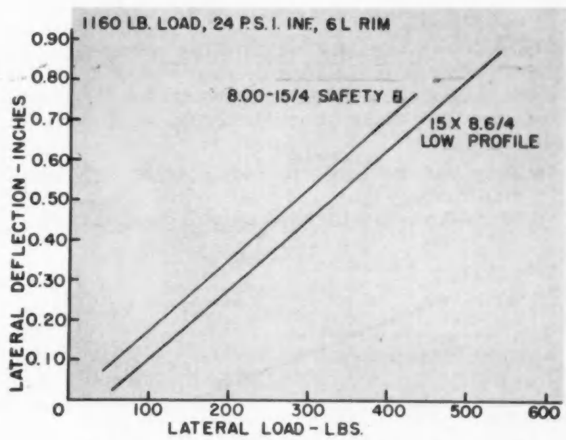

Fig. 2 — Lateral stiffness is better with today's low profile tire.

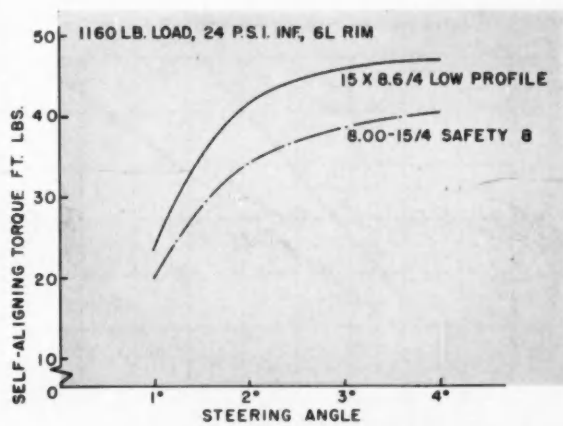

Fig. 3 — Low profile tires bring about greater self-aligning torque.

RUBBER SPRINGS

between universal joint centers up

Excerpts from paper by

P. J. Mazziotti

Dana Corp.

THE size and capacity relationship of rubber torsional springs make them a good way to increase torsional flexibility between universal joint centers. Features that make them desirable as a resilient unit include:

- They can be made to oscillate through large amplitudes.
- They can carry the transmitted torque and remaining oscillations without having to flex through high-frequency misalignment.
- They can be fitted between universal joint centers away from the highest temperatures and installation problems at each end.
- With reasonable proportions, they can be lightly stressed for long life.

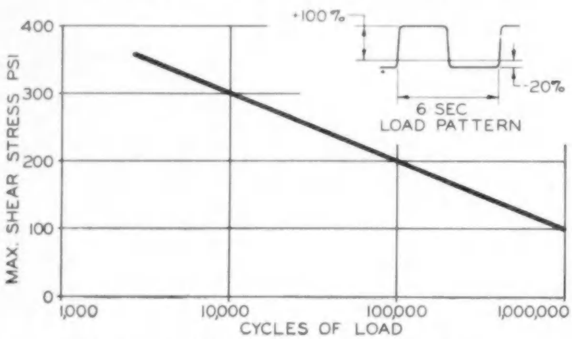

Fig. 1 — Load-life curve for rubber torsion springs.

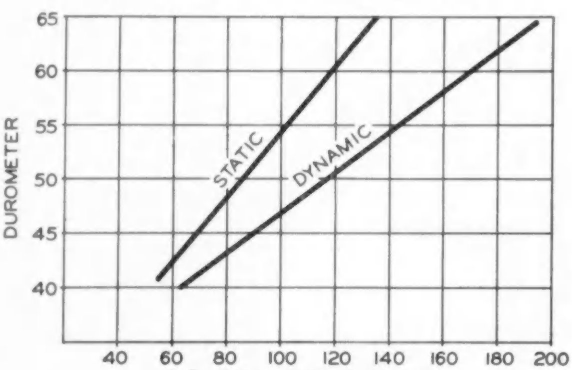

Fig. 2 — Rubber durometer versus shear modulus.

To calculate the characteristics of a particular rubber spring under torsional load, the following equation can be used:

$$k = \frac{\Gamma}{\theta} = \frac{4\pi L G r_i^2 r_o^2}{r_o^2 - r_i^2}$$

where:

k = Spring rate, in.-lb per radian
θ = Angle of twist, radians
Γ = Torque, in.-lb
r_i = Inside radius, in.
r_o = Outside radius, in.
L = Length of rubber, in.
G = Shear modulus of rubber, psi

For use in this equation, working value must be established for stress, modulus, and design proportions. A practical value for maximum shear stress can be established by analysing the static and fatigue capacity of the rubber unit. In connecting the engine to the transmission where operation is primarily over two times torsional resonance frequency, a very small part of the torsional disturbance is actually transferred through the connecting drive line. It can be reasonably assumed that if continuous operation at torsional resonance is avoided fatigue life can be based primarily upon maximum engine torque.

An approximate load-life curve for a rubber torsional spring is shown in Fig. 1. The actual load-life relationship in this type of unit varies considerably depending upon many variables as follows:

1. Frequency of Load: Because of internal hysteresis, temperature will increase if fatigue cycles are at a reasonably high frequency. (Tests can be slowed down to the order of one cycle of loading per six seconds to keep maximum temperature low.)

2. Load Pattern: The shape of the load-time curve has an effect on the overall life of the unit. The results shown in Fig. 1 are based upon an approximate

torsional flexibility

square wave loading of plus 100% of test load to minus 20% of test load, as shown.

3. Rubber Properties: The strength of the rubber material, its bond strength at the point of maximum stress, the amount of internal damping, all have an effect on its fatigue life.

Material tested to obtain the load life curve (shown in Fig. 1) is in the range of 45–55 durometer natural rubber with comparatively low internal hysteresis.

4. Test Procedure: The fatigue test data obtained for Fig. 1 was obtained by fatiguing at low frequencies by successively applying torque load through an air motor drive. This type of unit does not wind up a spring to a fixed amplitude, it has the property of stopping at a given load at any amplitude where it occurs. It is assumed that a failure occurs when the original amplitude has doubled.

Test results show that bond strength at the inside diameter is the critical working stress limitation. To obtain long fatigue life at maximum engine torque, it would appear that S_s max should be designed for about 100 psi. This might be increased in some cases where maximum torque can occur only a few times and impulses are kept very low.

A working value for G (shear modulus of the rubber) can also vary considerably with natural physical properties of the elastomer. Fig 2 shows the approximate relationship between durometer and static and dynamic shear modulus. These values are reasonably accurate and offer a sound basis for design analysis. The dynamic modulus is of primary concern in establishing natural frequency values. From this curve it can be seen that the shear modulus will be in the order of 100 psi in the 45–55 durometer range.

These equations and curves provide enough information to anaylze the effects of a rubber torsional spring in a transmission-to-engine installation. A comparison can be made between the effects of using a short steel shaft unit which produces objectionable torsional resonance frequency and the improvements possible with the torsionally resilient rubber spring.

To Order Paper No. S180 . . .
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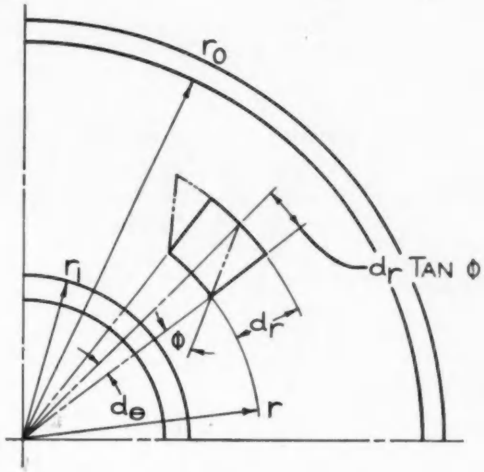
Derivation of equation



$$\Phi = \frac{S}{G} = \frac{\Gamma}{2\pi r^2 LG}$$

where:

G = Shear modulus of rubber
S = Shear stress at radius r, psi

$$d\theta = \frac{1}{r}\tan\left[\frac{\Gamma}{2\pi r^2 LG}\right] dr$$

A tangent function can be expressed as a series solution as follows:

$$\tan X = \left[X + \frac{X^3}{3} + \frac{2X^5}{15} + +\right]$$

Since this series converges rapidly, a reasonable approximation can be made by using the first term only. Using this simplified solution:

$$d\theta = \frac{\Gamma dr}{2\pi r^3 LG}$$

$$\theta = \frac{\Gamma}{2\pi LG}\left[-\frac{1}{2r^2}\right]_{r_i}^{r_o}$$

$$\theta = \frac{\Gamma}{2\pi LG}\left[\frac{1}{2r_i^2} - \frac{1}{2r_o^2}\right]$$

$$k = \frac{\Gamma}{\theta} = \frac{4\pi LG r_i^2 r_o^2}{r_o^2 - r_i^2}$$

10 criteria to control RELIABILITY

Based on a paper by

H. G. Spillinger

Boeing Airplane Co.

"RELIABILITY is the probability of a device performing its objective adequately for the period of time intended and under the operating conditions encountered."

Reliability is an engineering consideration — a design parameter based on these elements:

1. Probability — Reliability is, in a sense, a pre-assessment of a device's capabilities and a forecast of its performance. To control reliability emphasis must be placed on the development and use of predction techniques.
2. Performance — The device must work!
3. Time — The device must work as long as required by the customer.
4. Environment — All potential operating conditions of the device must be considered. Reliability based solely on laboratory operating conditions is not very meaningful. The possible degradation effects of shock, vibration, acoustics, temperature, dust, humidity, radiation, handling, storage, and the like must be evaluated and related to the required reliability.

Reliability programs should contain certain basic criteria. The following were established by the Air Materiel Command about two years ago, to evaluate the reliability programs of their weapon system contractors. The criteria are equally applicable to any manufacturing situation.

1. Concept and approach

The overall program should reveal an appreciation of the importance of reliability and of the necessity for an organized approach to its attainment. There should be recognition of the fact that reliability must be inherent in the basic design, that improvement is accomplished best in the early stages of development and test, and that the maintenance of reliability extends through the life cycle of a product. The program should indicate an awareness of reliability practices and the extent to which they are applicable. Specifically, the degree of reliability to be attained should be stated in quantitative terms, and the considerations of environmental and operational conditions should be clearly defined. There should be a statement of existing or potential "short-comings" and explanation of basis for "trade-off's" with other design parameters, such as performance, accuracy, weight, and cost. The progressive steps toward the reliability objective should be outlined, and should lend themselves to periodic reporting and progress analysis.

2. Organization

The reliability division should have an important position within the overall management organization. This will provide not only for the establishment of policy, but also for the complete implementation of the established policy. Policy can be outlined effectively by representatives from the executive office and the operating divisions. Implementation can be accomplished by granting assignment authority to this policy group or by creating a line organization with assignment authority. In either case, authority for assignment of specific responsibilities must be established. It must cover the engineering, manufacturing, quality control, and purchasing functions, integrating them into an effective program. There should be a director or manager to provide the necessary coordination, at both the policy-setting and operating stages. The director should be responsible and have authority for making sure that the necessary services (data processing, drafting, training) are provided as needed by the program and for seeing that the executive offices are informed of, and in accord with, all aspects of the reliability program.

3. Programming

There should be a time-phased plan covering each point of the reliability policy and all activity comprising the program. The authority and responsibility of the head of each working group should be clearly outlined so that specific reliability activities can be directed and their accomplishment measured,

both as to progress and completion. All reliability activities should be scheduled so that they are properly phased, where phasing is required, and so that they may be accomplished when required. The program should be so well defined that the people, skills, facilities, and elapsed-time requirements for each specified activity can be estimated with sufficient effectiveness to establish program cost.

4. Quality control

While the function of quality control is concerned primarily with determining compliance with existing specifications and acceptance criteria, this activity can also contribute substantially to reliability by feedback to and close liaison with engineering, manufacturing, and purchasing elements of the organization. This requires that the organizational stature of quality control be such that it has equal access to the ear of management at the reliability policy level and partnership participation at the working level. In operational procedure, quality control must utilize any standards and criteria that experience and state-of-the-art have indicated will contribute to improved reliability. Such procedures could include pre-award surveys, contractual requirements, qualification testing, acceptance criteria, assistance rendered by prime contractor, feedback data, and corrective action resulting from such data.

5. Reliability requirement studies

There should be full appreciation that reliability demands quantitative treatment (which involves advance study) — that it is not sufficient to wait for failure reporting to set the pattern. Such studies should be aimed at establishing quantitative requirements to include specification of required function (performance limits), operating time, and environment as well as the required reliability. The requirements should be realistic, determined as early as possible, and revised as necessary. Environmental conditions specified should cover all phases from factory to the target, including shipping, storage, handling, and flight.

6. Qualification testing

There should be a realization of the need to qualify all systems, subsystems, and equipment before the production in quantity is undertaken. This concept requires a time-phased scheduling of qualification testing to insure completion by the time the first production article comes into being. The basis for qualification should be defined to the extent of indicating that tests include not only compliance with government and contractor specifications, but also whatever additional requirements have been determined as a result of reliability requirement studies, engineering data and analyses, or special environment. If based on arbitrary assumptions in lieu of accurate knowledge of requirements, this fact should be noted together with the assumptions. Availability of adequate testing facilities, both prime or sub-contract, should be referenced.

7. Acceptance criteria

There should be an outline of the measures taken to insure that, once an item has been qualified, the follow-on quantity production does not fall below the established standards, particularly with respect to reliability. There should be expression of the degree of application of these procedures (100% or sample) and the corrective action that is taken to improve both the product and the procedures when articles do not comply with the acceptance criteria established.

8. Failure and deficiency reporting, analysis, and correction

There should be reference to the sources of failure and deficiency data both from within (manufacturing, quality control, test) and without (technical representatives, field service, and the like). The procedures for collection, recording, summarizing, presenting, revising, and analyzing data should be outlined. Most important, the organization, facilities, procedures, and follow-up that insures that corrective action is accomplished should be clearly described.

9. Relationship with vendors and subcontractors

In the selection of vendors and subcontractors, it should be evident that there is an evaluation of the supplier's ability to meet the reliability requirements; that some sort of rating system is utilized with possible inclusion of an approved listing of sources for particular types of materiel. There should be reference to the completeness of engineering data, including test and inspection criteria, that is incorporated in purchase orders and subcontracts. A statement should be made describing the surveillance maintained over suppliers other than inspection and test, such as review of quality control system, drawing and engineering change control, specification review. There should be a procedure for supplying vendors and subcontractors with malfunction and deficiency data and corresponding follow-up on corrective actions. Reference should be made to the extent of assistance that is rendered suppliers in solution of immediate problems, in improvement suggestions, in providing information on new methods and techniques in engineering and manufacturing.

10. Training (reliability indoctrination)

Reliability is to a great extent education. Therefore, there is a need for organized training with relation to reliability. In addition to courses designed to raise skill levels and hence improve reliability, effort should be directed to making personnel reliability conscious and making them aware of how their particular jobs can contribute to the reliability of the end product. How this is accomplished (lectures, films, or formal courses) and to what extent each level of employment (manager, engineer, technician, worker) participates in reliability training programs should be outlined.

To Order Paper No. S173 ...
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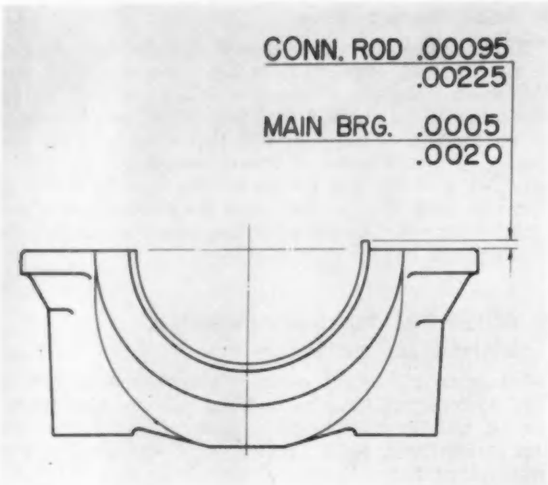

Fig. 1 — When crushing action of bearing shells during assembly was found to be producing different connecting rod clearances from those desired, redimensioning components corrected error at American Motors.

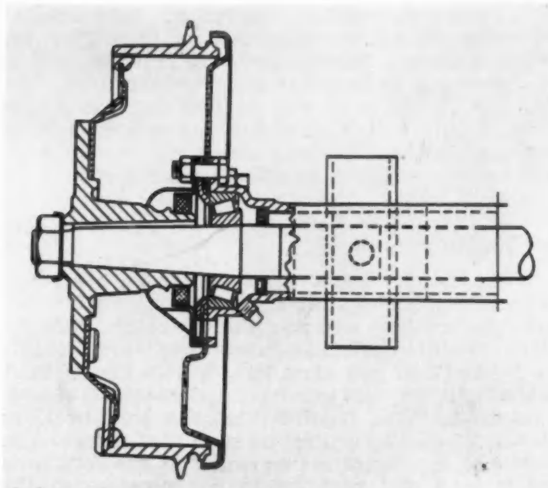

Fig. 2 — Annoying clicking sound in rear axle was found to be caused by slight inaccuracies in axle shaft taper and internal taper of hub. Correction was made by using type of axle shown in Fig. 3.

Reducing the human element in

Based on paper by

D. H. Monson

American Motors Corp.

TO IMPROVE quality and thereby assure customer satisfaction, American Motors has taken measures to reduce to a minimum the human element in production. By way of illustration, two examples can be cited — one relates to connecting rod and main bearing clearances; the other to rear axle to hub clicking.

Assuring Proper Bearing Fit

Evaluation of the quality of the 195.6 cu in. displacement engine revealed actual connecting rod clearances were approaching 0.002–0.0025 in. even though the desired clearance was between 0.001 and 0.0015. Through experimentation it was determined that the additional clearance was obtained during assembly due to the crushing action of the bearing shells. This is shown in Fig. 1.

Some members of the organization believed curative action lay in selective fitting of crankshafts, connecting rods, and connecting rod bearing shells. But the solution to the problem was to redimension the connecting rod bearing bores, the bearing shell thicknesses, and the crankshaft pin bearing diameters so that calculated vertical clearance was a minimum of minus 0.0003 to plus 0.0015.

A similar study was made of main bearing clearances and by re-evaluation of the various dimensions of the components, such as bearing bores, thickness of bearing shells, and crankshaft main bearing diameters, a theoretical vertical clearance of plus 0.0001 to 0.0023 was obtained. The re-evaluated clearances of all components are shown in Table 1. This re-evaluation and restacking of tolerances eliminated the need for selective fitting. And with a successful outcome in this area, a similar treatment was applied to valve stem and valve stem guide clearances.

Eliminating an Objectionable Noise

Correction of a rear axle shaft to hub clicking represents another example of eliminating the human element in production to increase customer satisfaction. This clicking was particularly noticeable and objectionable under conditions of reversal of engine torque. The axle used at that time was of the semifloating type with the hub and drum keyed to the axle shaft on a 1 in. per ft taper. Slight inaccuracies on both the axle shaft taper and the internal taper of the hub produced the clicking (Fig. 2).

A solution to this problem would have been to adopt an axle shaft of the flanged type, but it was felt inadvisable because of the costly tooling program involved. Instead, a serrated type of axle shaft was developed, as shown in Fig. 3. One will notice that the conventional taper of the former design has been relieved by 3/64 in. on a side for a distance of approximately 1¼ in. The actual serrated portion is approximately ⅝ in. in length. The serrated section of the taper is approximately 0.012 in. on a side larger than the theoretical true taper of 1 in. per ft for an axle shaft of this particular

Fig. 3 — Development of serrated type of rear axle eliminated clicking noise, which was most objectionable under conditions of reversal of engine torque.

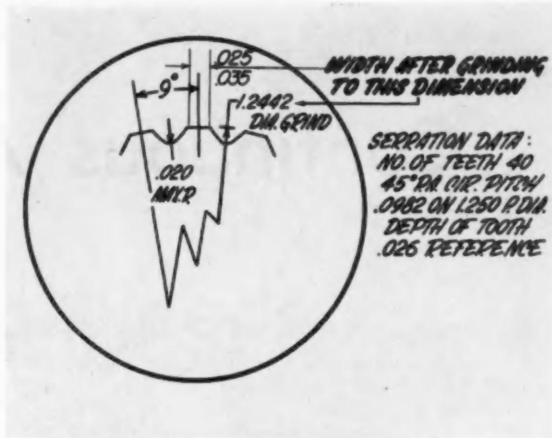

Fig. 4 — Axle shaft is machined by conventional method, but serrations are rolled in, after which shaft is hardened and ground to size, producing serrations of 0.025-0.035-in. width.

production

size. To accommodate this serrated axle shaft, the hub is the same as the conventional taper hub, except for the omission of the keyway and the addition of a relief groove to provide clearance for the end of the serrations. The internal taper of the hub is serrated by the broaching action of the shaft at the time of assembling the hub to the serrated shaft.

Producing the Serrations

Fig. 4 shows the design of the serrations in detail. The width of each serrated tooth at its intersection with the finished OD of the shaft is 0.025–0.035 in. The circular pitch is 0.0982 on a 1.250 pitch diameter and the tooth pressure angle is 45 deg. The total number of tooth serrations for this particular shaft diameter is 40 and serration depth is approximately 0.026 in. Axle shafts of this design are machined by the conventional method except for the rolling of the serrations which is performed on a Read rolling machine. After rolling, the shaft is hardened and ground to size to produce 0.025–0.035 width of serration.

The hub is assembled to the shaft by applying a 27,000-psi pressure at the end of the hub, using a hydraulic cylinder pump with an intensifier to produce a 500-psi line pressure. This pressure is needed to press serrations into the hub, thereby making a click-free assembly (Fig. 5). The complete assembly of shaft and hub is checked with an air-leak gage to insure a perfect seat of the hub taper to the shaft taper.

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... on which this article is based, turn to page 6.

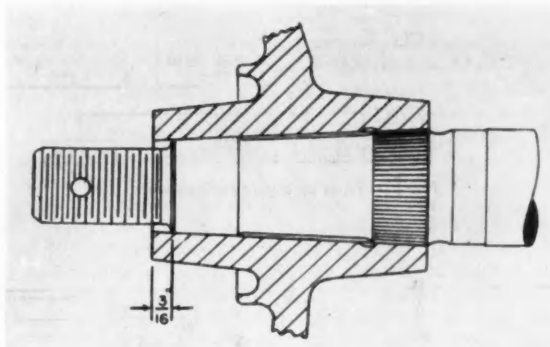

Fig. 5 — Hub is assembled to shaft by applying 27,000-psi pressure. This presses serrations into hub, making a click-free assembly. Check with air-leak gage insures perfect seat of hub taper to shaft taper.

Table 1 — Connecting Rod and Main Bearing Clearances

	Min	Max	Total Tolerance
Connecting Rod Bearing Bore	2.2080	2.2085	0.0005
Thickness of Bearing Shell — Upper	0.0564	0.0561	0.0003
Thickness of Bearing Shell — Lower	0.0564	0.0561	0.0003
Crankshaft Pin Bearing Diameter	2.0955	2.0948	0.0007
Theoretical Vertical Clearance	−0.0003 to	+0.0015	(0.0018)

	Min	Max	Total Tolerance
Crankcase Main Bearing Bore	2.625	2.626	0.001
Thickness of Bearing Shell — Upper	0.07255	0.0723	0.00025
Thickness of Bearing Shell — Lower	0.07255	0.0723	0.00025
Crankshaft Main Bearing Diameter	2.4798	2.4791	0.0007
Theoretical Vertical Clearance	0.0001 to	+0.0023	(0.0022)

Continuous Air Source Units

Increased Jet

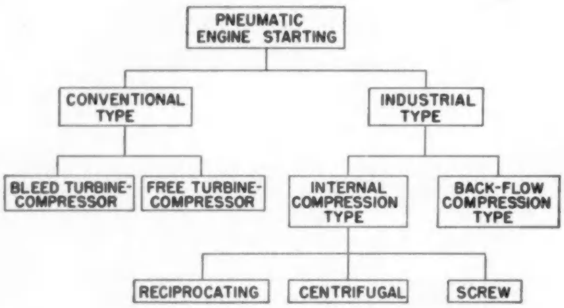

Fig. 1 — Types of engine starting units.

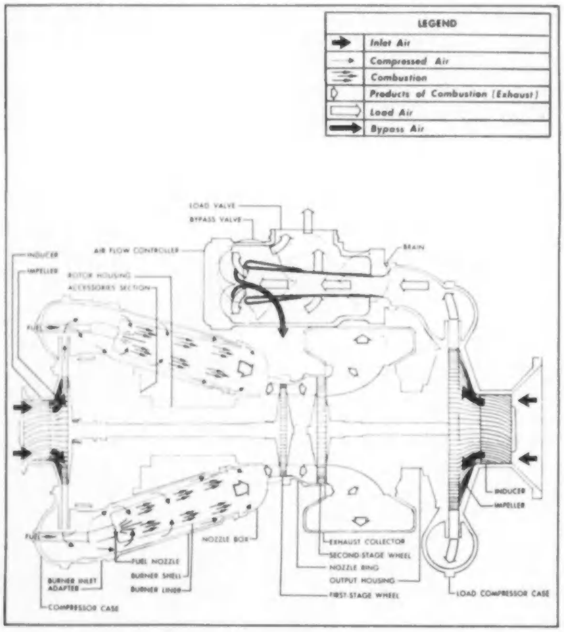

Fig. 2 — Airflow schematic of free turbine unit

Based on paper by

F. P. Carr, Jr., and Stanley Kalikoff

Consolidated Diesel Electric Corp.

CONTINUOUS air source units to meet the pneumatic ground service requirements of turbine-driven aircraft can be divided into three general classes:

- Engine starting units.
- Cabin air conditioning service units.
- Combination units — engine starting plus air conditioning equipment.

The performance of many of these units has been established by actual service; other systems are still in the development stage.

engine starting units

Fig. 1 shows the types of continuous air source units in this class. There are two basic groups: "conventional" start carts and "industrial" start carts.

The conventional type, used extensively by the U.S. military, includes gas turbines of the air bleed and free turbine categories. The basic operating principles of bleed and free turbines are the same.

In the gas turbine, compression and expansion occur in separate chambers, and combustion is continuous. Energy is received from the combustion of compressed air and fuel. This energy is converted to useful power by expanding the resultant gases through two separate turbines. In the bleed type of unit, a single turbine is utilized for this conversion.

Fig. 2 shows an airflow schematic of a free turbine unit, whose gas-producer compressor is of the centrifugal type. The air is fed at a pressure of approximately four atmospheres from the compressor scroll to the burners. Each burner has a means of injecting fuel, and a spark plug or similar device for ignition. Not all of the air entering the burners is used for combustion; about three-fourths of this air flows in along the liner walls and forms an insulating blanket between the walls and the flame. As the heated air is expanded, it mixes with the

Will Meet

Aircraft Servicing Needs

products of combustion and passes to the nozzle box. The hot gases from the nozzle box are directed against the blades of the first-stage turbine, rotating it at high speed. This turbine drives the gas-producer compressor's inducer and impeller. The gases are then directed against the second-stage turbine, which also rotates at high speed. After leaving the second-stage turbine, the gases are expelled into the atmosphere.

The second-stage turbine drives the "starter" air compressor. This compressor feeds air to a flow controller, which matches air output against air demand to prevent compressor surge. This is done through bypassing or dumping excess air.

In the air bleed compressor, a portion of the air flowing through the unit is drawn off after it has been compressed, but prior to its entrance into the combustion chamber. This bleed air passes through a control valve, into flexible ducting, and thence to the engine-mounted pneumatic starter in the aircraft. The bleed air used for starting is clean. Control of the bleed turbine compressor is similar to that of the free turbine unit, except that the excess air continues on through the burners and turbine, and is exhausted to atmosphere.

Fig. 3 shows the range of flows, temperatures, and pressures available from the bleed turbine. Performance of the free turbine is similar.

Industrial start carts, while largely unproved by actual service, promise to offer lower operating and maintenance costs in those applications where size and weight are not primary considerations. These carts are composed of highly reliable components combined in a variety of ways to form continuous air source packs. The units may be powered by gasoline, diesel, or gas engines.

One continous air source pack consists of two gasoline engines driving Roots blowers staged together with intercoolers, to provide the proper discharge pressures. The Roots blower utilizes back-flow compression, and has been used for many years for engine supercharging, cabin pressurizing, and other applications. Back-flow compression is not as efficient as a system where compression takes

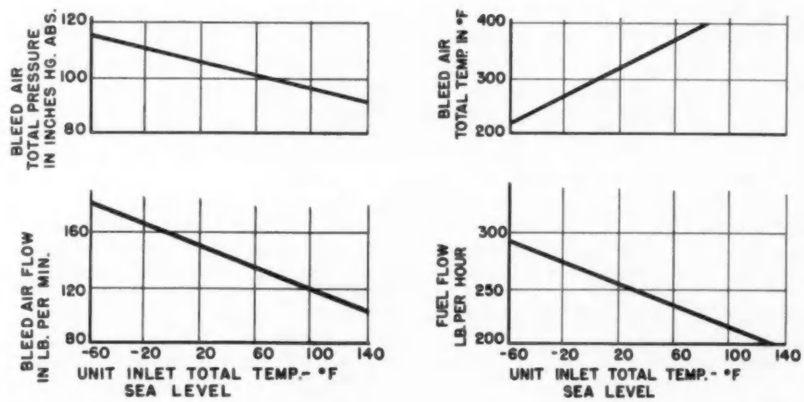

Fig. 3 — Performance of typical bleed air turbine compressor.

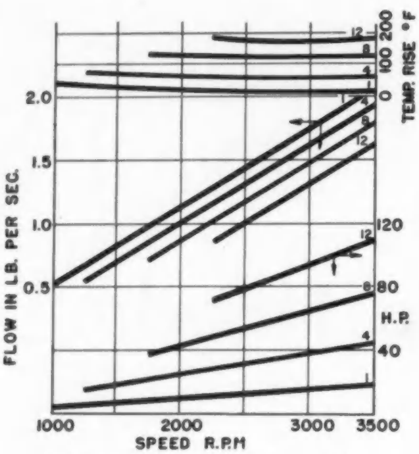

Fig. 4 — Performance of typical Roots blower.

Jet Aircraft Servicing Needs

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place within the confines of the compressor. Fig. 4 shows the performance of a typical Roots blower.

Another industrial unit utilizes a modified Lysholm, or screw compressor, driven at high speeds, through a gear box and clutch, by a single diesel engine.

Fig. 5 shows the operating characteristics of a typical screw compressor. Operation over a wide range of pressure ratios at relatively high efficiencies is possible since the compressor is not limited by surge considerations. Air delivery rate is basically a function of compressor speed, regardless of operating pressure ratio. The efficiency of the unit will fall when operating pressure ratios are in excess of the "built-in" or design pressure ratio. This can occur as a result of back-flow compression if the air delivery exceeds the requirement of the load and the volumetric capacity of the delivery system. The further the operating pressure ratio varies from the built-in pressure ratio, the more it tends to act like a Roots blower.

Fig. 6 compares the amount of work required under given conditions for a Roots compressor and a Lysholm compressor.

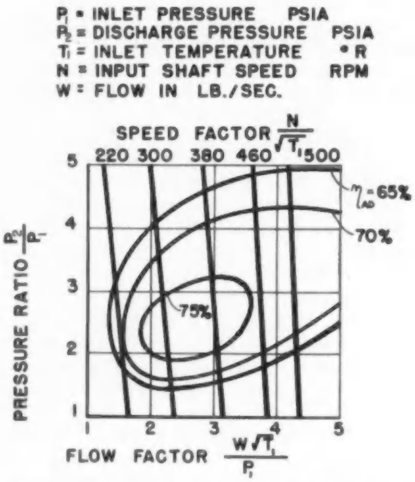

Fig. 5 — Performance of typical screw compressor, showing wide range of operation at high efficiencies.

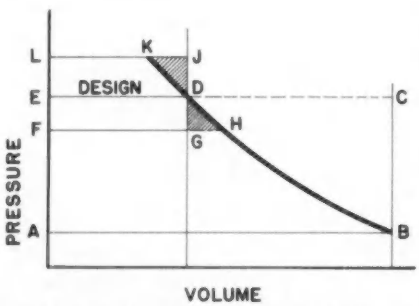

Fig. 6 — Comparison of work required by Roots compressor and Lysholm compressor for design pressure ratio *E/A*. Work done by Lysholm compressor at design point is area *ABDE*; work done by Roots compressor is *ABCE*. Excess of power required by Roots over Lysholm is *BCD*. In the Lysholm compressor, if back-pressure (*L*) is greater than design (*E*), area *DJK* represents power required over that if unit were specifically designed for built-in pressure ratio *L/A*. If back-pressure is less than design, excess power expanded over specifically designed unit is represented by area *DGH*.

cabin air conditioning service units

Fig. 7 shows the groups into which air conditioning service units can be divided. The major divisions are vapor cycle and air cycle systems. Vapor cycle systems have been widely used in aircraft support equipment. Air cycle systems are, for a given tonnage output, smaller and lighter than vapor cycle systems. The rotating parts of air cycle systems rotate at high speeds — ranging from 35,000 to over 100,000 rpm. However, many years of practical operating experience with these units have been acquired by the Armed Forces; and manufacturers have become proficient at holding the close tolerances required.

The vapor cycle system utilizes "halogenated hydrocarbon" refrigerants — hydrocarbons of the methane or ethane series which have had the hydrogen replaced by chlorine or fluorine. They are industrially known as Freon or Genetron.

The heat necessary to vaporize the refrigerant is obtained from the air which is to be cooled. Roots and centrifugal compressors are used for moving the low-pressure, conditioned air through the system to the aircraft cabin. Control of the conditioned air temperature may be obtained by mixing the conditioned air and warm air (air side control), or by regulating the refrigerant temperature or flow (vapor side control). Humidity controls are also required under certain conditions.

The air cycle system uses air as a refrigerant, operating from a source of high-temperature, high-pressure, clean air. The two most common variations are the "simple" and "bootstrap" systems.

In the simple system, the temperature may be regulated by mixing cold air from the expansion turbine with warmer air which has been bypassed around the expansion turbine. Basic flow control is obtained by dumping.

Cooling air by expansion causes precipitation of moisture in the form of very fine droplets or fog, which should be removed. Water separators, which coagulate the fine particles into larger, more easily removed droplets, are 75–85% effective. The remaining entrained moisture is readily re-evaporated in the duct system and cabin.

The bootstrap system is a common variation of the simple system. It is used to advantage where there is a free source of ambient air such as aircraft ram air, and when it is desirable to increase the pressure to the expansion turbine somewhat above what is ordinarily available. The difference between this system and the simple system is that in the bootstrap system the air passes from a primary heat exchanger to a compressor, where its pressure and temperature are increased. The air temperature is then reduced in a secondary heat exchanger. From there it flows through the expansion turbine. The energy extracted from the air drives the compressor on the turbine shaft. The bootstrap system requires separate ambient cooling air blowers for the primary and secondary exchangers.

combination units

Combination units consist of jet engine starting equipment with air conditioning equipment added. These devices are practical since the air conditioning may readily be interrupted during the brief period necessary to start the engines.

Combination sources consist of various combinations of conventional or industrial starting units with air cycle or vapor cycle systems added. When size and weight are primary considerations, the gas turbine–air cycle combination is preferable. If these are not the basic criteria, industrial engine starting units and vapor cycle systems may be investigated from an operating point of view.

Combination pneumatic service packages are often employed as part of a multipurpose vehicle capable of fulfilling all ground support requirements of a particular type or family of aircraft.

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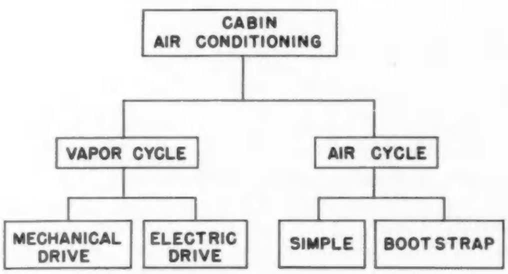

Fig. 7 — Types of air conditioning service units.

Earthmovers Need Better Designed Tires

Based on paper by

D. A. CLENDENEN Firestone Tire & Rubber Co.

IF off-the-highway vehicles are to give racehorse service, tires must be designed for them. The trend to larger vehicles, higher speeds, more torque at drive wheels, and all-wheel drives has made present tires inadequate.

Tires capable of high-speed operation are a prime necessity. Tread thickness should be reduced to minimize the insulating effect of the rubber tread, and this should be coupled with a modification in tread design to aid in temperature reduction. Tires should also be larger for comparable loads.

As speed and length of haul increases, tire capacity decreases. As loads are lightened, there is less deflection of the tire and a reduction in heat generation. A recent field survey revealed that, on an 8-mile haul with a 145,000-lb gross vehicle load, an increase of 5000 lb in payload caused a stabilized temperature to rise 7 F in one trip. This points up the critical nature of load on heat generation.

Problem of Compounding

A tread material compounded for maximum cutting resistance tends to generate more heat, due mainly to the type of reinforcing carbon black used. Compounding must, therefore, be altered to insure coolest running characteristics for the long haul job. It will not be designed for maximum cutting and abrasion resistance, but for resistance to heat separation.

Fig. 1 shows a standard rock service tire flanked by two types of tires which have been undergoing evaluation for 30-mph, short-haul (1.5 miles or less) service. The tire on the left has had material removed from the center of the bar from which heat dissipation is most difficult. Differentials as great as 20 F have been measured with this type of tread. On the right is a skinned-down tire, having reduced skin and shoulder gages for cooler operating characteristics. This is probably the tread to expect for high-speed earthmoving.

To Order Paper No. S185 . . .
on which this article is based, see p. 6.

Fig. 1 — Tire at left has material removed from center of bar for better heat dissipation. At center is standard rock service tire. Skinned-down tire at right may be the cooler tire of the future.

A new look at

Turbine fuel filtration

Based on paper by

G. T. Coker and H. R. Heiple, Shell Oil Co.
and R. G. Davies, Shell Oil Co. of Canada

FUEL filter technique is one of the main problems to solve in finding the overall answer to turbine fuel cleanliness.

"Five-micron" filter/separator equipment, which was thought originally to provide a cutoff in the 30-50-micron range and certainly to remove the larger particles, has not performed as expected.

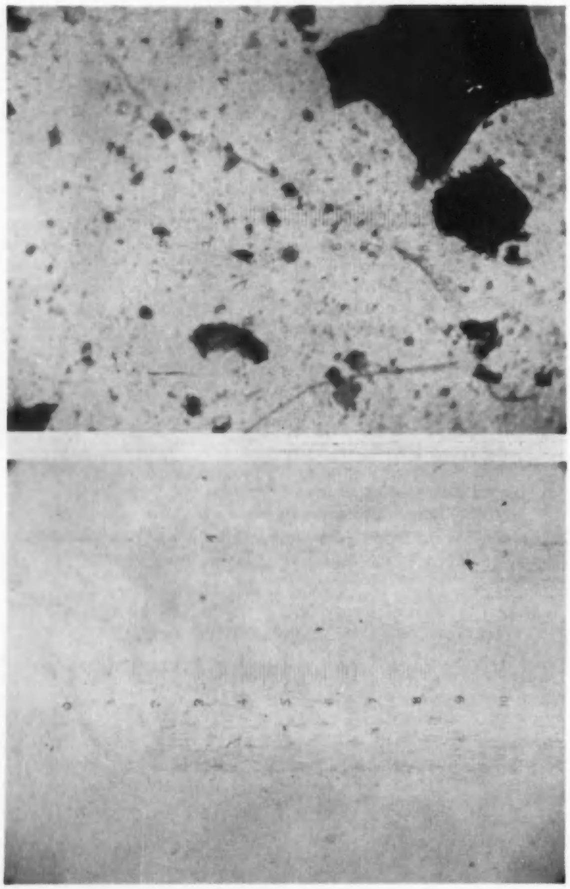

Fig. 1 — (Top) photomicrograph of material removed from a fuel sample taken on startup after installation of new elements by passing the fuel through a millipore filter. (Bottom) by contrast, an effluent sample representative of equilibrium conditions.

Tests show particles of 150-micron size are found regularly in effluent streams (Table 1). Moreover, if the percentages of particles in influent and effluent streams are compared, the particle size distribution is found to be not appreciably altered (Table 2). Percentagewise, there are just as many 5-micron particles in the effluent as in the influent. In view of these two unhappy facts, statements regarding "five-micron" filtration are confusing.

Media migration

One iron-clad requirement should be that filtration equipment must not generate contamination. Some portions of such equipment are fibrous in nature and should these enter the fuel system, they could play havoc. Although this problem of media migration appears to be confined to new elements, in some instances it can be of considerable magnitude, as shown in Fig. 1.

It appears to take some 15–20 min to rid new elements of these loose fibers. For this reason, it seems advisable to recirculate fuel through the filter after installation of the new elements for at least 30 min, certainly for some units.

Phenomenon of unloading

When testing equipment in the laboratory under the cyclic conditions of abrupt starts and stops, which are characteristic in service, a phenomenon denoted as "unloading" has been observed. It occurs on partially loaded elements immediately after startup and tests show the solids contamination level to increase by a factor of approximately 10 (Table 3). Similar observations appear to be true for water.

Pleated paper separator cartridges are extremely susceptible to such water "unloading" when in a horizontal position, and such unloading of either solids or water has been observed in two-stage units as well as single-stage equipment.

As in the case of media migration, the quality of the effluent stream appears to return to equilibrium within 30 min. This time interval is disturbingly long in view of the fact that it rarely takes longer than 30 min to fill a refueler. Thus, to minimize the effects of unloading when using present filter designs, it would be advisable to provide for recirculation through the filter before filling refuelers. While practical to do so, the same procedure would be most difficult to apply to mobile equipment before filling aircraft. Hence, unless unloading of filter/separators installed on mobile equipment can be

eliminated by improved filter designs or by practical means for recirculation, there remains an uncontrolled source of fuel contamination.

Per cent distribution criterion

The performance of a filter-separator is usually described in terms of per cent removal of solids in some prescribed test. This value will be greater than 99% in most cases, which tends to instill a measure of confidence in such equipment. However, the item of prime importance is the quality of the fuel being delivered, hence the effluent stream should be given prime consideration, irrespective of the influent. The preliminary data in Table 4 show the quality or solid contamination level of the effluent to be reasonably independent of the influent concentration. For this reason, "per cent removal" figures can give a misleading indication of a filter's ability to insure delivery of clean fuel.

Water wetting of cartridges

Many filter/separators employ two stages, the last being termed a water stripper, separator, or polisher cartridge. When the elements are pleated and in the horizontal position, the upper pleats form natural traps for water. After a sufficient time, the water either wets the element and comes through or it will be forced through during cyclic-type operations. Once any treated paper element has been saturated with water, it no longer performs its function. And this would suggest the use of other materials for separator cartridges.

Effect of additives

Corrosion inhibitors and other additives are used currently in military jet fuels and, undoubtedly, the future will see such materials in commercial turbine fuels. This suggests the need to assess the effect of such materials on the performance of filter/separators. Usually, such equipment is limited to use on fuels having interfacial tensions (IFT) somewhere above 20-30 dynes per cm. Limiting the performance on the basis of IFT may not be justified in the light of some recent data. Something other than IFT appears to be the controlling factor.

Quality control

Through the cooperation of the filter manufacturers in these investigations, much has been learned about quality control, hence two items are proposed for consideration:

- From each batch of elements, a number should be tested to failure on both solids and water. In addition, some elements should be retained for future reference should problems arise in the field. This, of course, implies some means of identifying batch numbers on any particular element.
- Since the finished units perform only as well as the poorest element, some means should be provided for testing the performance of each and every element before delivery. Perhaps the air bubble test could be modified for production use.

To Order Paper No. 47T . . .
. . . on which this article is based, turn to page 6.

Table 1 — Performance of Various Filter Separators

Size Range, microns	Influent	Effluent A	Effluent B	Effluent C	Effluent D
3–5	3680	29.4	—	5.1	125
5–10	2542	13.9	14.1	3.9	70
10–20	2094	11.0	9.0	2.4	25.7
20–30	315	1.9	1.6	0.5	3.7
30–50	202	0.7	0.6	0.2	1.0
50–100	111	0.7	0.6	0.3	1.3
> 100	40	0.5	0.8	0.1	0.2
No./ml > 30μ		1.9	2.0	0.6	2.5

Table 2 — Distribution of Particles by Per Cent

Size Range, microns	Average Influent	Effluents from Filter A	B	C	D
3–5	41.0	50.6	49.4	36.3	40.8
5–10	28.3	23.9	26.9	31.1	31.2
10–20	23.3	18.9	18.0	24.2	19.2
20–30	3.5	3.3	3.2	4.3	4.0
30–50	2.2	1.2	1.1	1.4	1.6
50–100	1.2	1.2	0.7	2.2	2.4

Table 3 — Unloading of Filter Separators

Particle Size, microns	Equilibrium Condition, no./ml	On Startup, no./ml
5–10	41.4	334
10–20	26.7	185
20–30	5.0	51.8
30–50	3.3	27.0
50–100	1.9	20.3
> 100	1.4	11.3
Total	79.7	629.4

Table 4 — Effect of Varying Influent Contamination

Size Range, microns	Influent, no./ml	Effluent, no./ml	Influent, no./ml	Effluent, no./ml
		Filter A		
5–10	81.3	59.2	3680	35.1
10–20	54.6	25.8	2670	14.4
20–30	17.1	5.1	418	4.1
30–50	8.4	1.6	327	2.1
50–100	0.6	0.9	202	1.5
> 100	0.1	0.7	157	0.9
Total	162.0	93.3	7454	58.1
		Filter B		
5–10	46.2	20.4	4950	7.2
10–20	34.6	11.1	1570	3.3
20–30	32.4	1.8	670	0.6
30–50	12.6	0.2	205	0.2
50–100	11.2	0.2	56	0.2
> 100	1.4	0	15	0
Total	138.4	33.7	7466	11.5

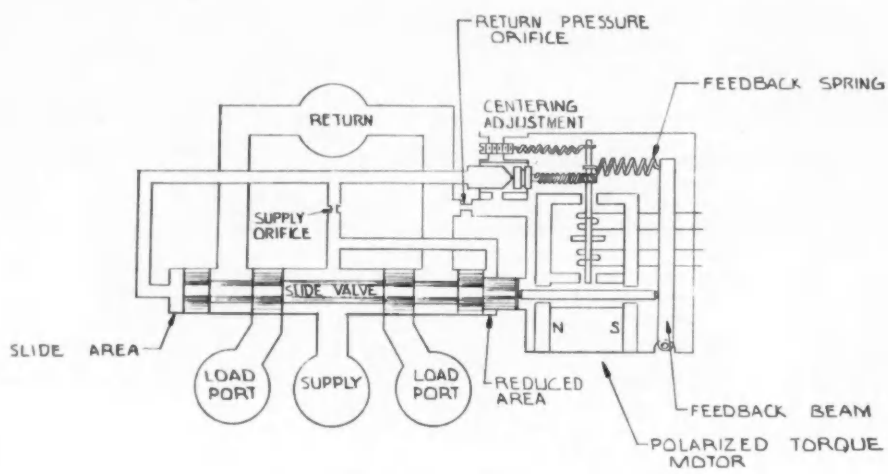

Fig. 1 — Schematic diagram of Cadillac valve FC2.

New Contamination Measuring

uses servo valve to detect dirt in

HERETOFORE, the equipment used to measure fluid contamination in hydraulic systems has been both complicated and expensive. In addition, it did not relate contamination level readings to the effects contamination has on a hydraulic system.

The method described here, on the other hand, is designed both to measure the contamination directly and also to permit continuous sampling of the hydraulic system fluid without having to replenish fluid drawn off for analysis.

It is based on the fact that the servo valve is the most sensitive component in the system to contamination. It quite logically uses a servo valve, suitably modified, to do the measuring.

A separate extra-sensitive valve must serve as contamination meter — rather than any of the servo valves installed in the system. The reason is that the meter valve must be designed to detect an increase in contamination level before it becomes detrimental. Only in this way can contamination level be maintained well below the level that would begin to affect the flight control system noticeably.

Based on talk by

Richard E. Osgood

Pilotless Aircraft Division, Boeing Airplane Co.

(To Subcommittee A-6D, Missile Fluid Power Systems, of Committee A-6, Aircraft & Missile Hydraulic & Pneumatic Systems & Equipment)

THE servo valve used to monitor hydraulic system contamination must be more sensitive to contamination than the valves being protected.

To attain this increased sensitivity, it is only necessary to modify some of the various factors that affect valve contamination sensitivity, such as:

1. In first-stage design: the orifice size, nozzle flapper spacing, and protecting filter characteristics.
2. In second-stage or slide and sleeve design: diametral fits, area of slide and sleeve contact, overlap on metering edges, and slide positioning force characteristics.

Valve design

To control contamination that might affect the first stage, the servo-valve contamination meter first stage should be identical to the first stages of the valves in the system. The orifice and nozzle configuration should be reasonably close to the same size or slightly smaller. Likewise, the orifice and nozzle protecting filters should be identical in their characteristics, within reasonable tolerances.

In the event of an orifice or nozzle plugging in the servo-valve contamination meter, the meter could

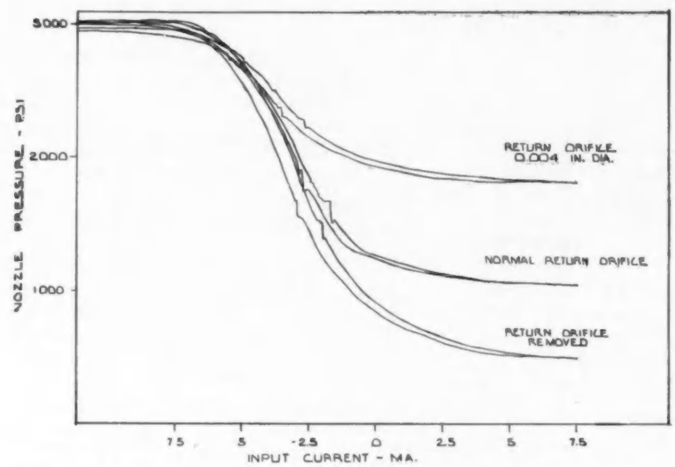

Fig. 2 — Nozzle pressure characteristics of Cadillac valve FC10-451A, serial No. 8537.

Method

hydraulic systems

not be put back into operation easily. Since this type of failure is due to buildup of contamination over a period of time, the proper procedure then would be to clean the system thoroughly and replace all the servo valves including the meter valve before continuing operation of the system. Internal protecting filters becoming coated with contamination would cause a failure of the same type and similar procedure should be taken. Failures due to plugged orifice or nozzles and coated protecting filters are rare in a system assembled with proper care and normal filtration.

The slide and sleeve or second-stage design should have essentially the same type of material, diametral fits, area of slide and sleeve contact, and metering edge overlap as the valves in the system. The meter would then be sensitive to the same type and size of contamination as the system servo valves. To cause the servo-valve contamination meter to be sensitive to lower levels of contamination than the system valves, the slide positioning pressure per unit input current must be reduced.

This may be accomplished by decreasing the size of the first-stage return pressure orifice shown in the Cadillac Gage Co. FC2 servo valve schematic diagram of Fig. 1. The nozzle pressure characteristic curve slope is reduced as shown in Fig. 2. This results in less force being available to move the slide for a given input current. The meter reading, being a function of hysteresis, will be proportionately greater than normal for a given amount of contamination. The reduced return pressure orifice size would probably cause the first stage to become slightly more sensitive to contamination. The physical dimensions would remain essentially the same for the upstream orifice and nozzle-flapper orifice but the pressure drops across them would be less and, therefore, less force to clear the orifices of fibers, which cause progressive buildup of smaller particles.

Where a number of different sizes or types of valves are used, certain factors must be considered to determine the proper valve type to select as a contamination meter. Contamination sensitivity in the second stage or slide and sleeve is related to the diametral fit and overlap, which in turn are generally established by the deadband and leakage requirements. Since some amount of overlap is necessary to prevent excessive leakage, then the diametral fit establishes the size of particles that may be trapped between a slide and sleeve. A hydraulic system generally contains more of the small-size particles than the large because system filter efficiency is reduced with particle size, and particles generated by surface wear are usually quite small. For this reason, the diametral fit of the slide and sleeve in the contamination meter should be the same as the smallest diametral fit of any of the valves in the system.

The pressure drop across the metering orifice drives the contamination between the slide and sleeve. The velocity of the fluid surrounding a particle determines the specific driving force and, therefore, the amount of friction developed between the slide and sleeve. As the overlap between the slide and sleeve decreases, the pressure gradient increases, which results in higher velocity and greater forces. Therefore, the overlap of the slide and sleeve in the contamination meter should be the same as the smallest overlap of any of the valves in the system.

Often, the valve manufacturer changes the flow gain of servo valves by altering the circumferential length of the metering edges of the slide and sleeve. Since the metering edge between the slide and sleeve is a major point of contamination sensitivity in the servo valve, it follows that (all other factors

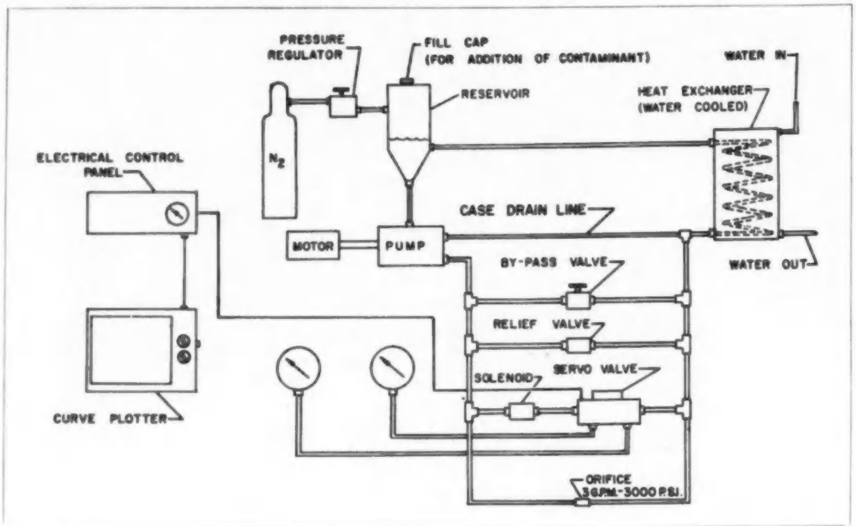

Fig. 3 — Hydraulic system for servo - valve contamination tests.

New contamination measuring method . . . continued

being equal) the more metering edge in the valve, the greater the contamination sensitivity. The servo-valve contamination meter, therefore, should have as much more metering edge as any valve in the hydraulic system being monitored. This suggests the valve with the greatest output flow should be used as a contamination meter.

Calibration tests

The first-stage return pressure orifice of Cadillac servo valve FC10-451A, serial No. 8537, was replaced with a 0.004-in. diameter orifice and contamination sensitivity tests were conducted. The contaminant, test procedure and results are as follows:

1. *Calibration Test Contaminant* — So that the calibration test would be realistic and practical, an artificial contaminant was chosen that duplicated the contaminant removed from a sample of hydraulic fluid taken from a typical missile system that had operated for about 50 hr (simulating the length of possible preflight test time). By laboratory analysis it was determined that about half (by volume) of the contaminant was metallic (primarily ferrous in nature) and half nonmetallic. An artificial contaminant was made up of two commercially available contaminants:

a. Fifty per cent by volume of AC fine dust (simulating nonmetallic contaminant).

b. Fifty per cent by volume of type SF carbonyl iron powder (simulating metallic contaminant).

The artificial contaminant was found to be about 95% of particles in the 0–5 micron range and the remaining 5% in the 5–40-micron range.

2. *Test Procedure* — The electro-hydraulic servo valve was placed in the hydraulic system shown in Fig. 3. The operation of the valve was observed by means of hysteresis curves taken in the null region as the contamination concentration or level was increased in steps with additions of the artificial contaminant.

The artificial contaminant was mixed with the hydraulic fluid by ultrasonic vibrations and the system circulated for about five minutes. An optional method of mixing the contaminant in the system without ultrasonic vibration can be accomplished by about 30 min of circulation, but this requires too much time and causes too much pump wear. To maintain constant conditions throughout the system, the fluid was circulated through an orifice at 3 gpm. The servo valve was operated in the system at each level of contamination just long enough to exercise the valve for about 10 sec and run the hysteresis curve.

3. *Calibration Test Results* — The hysteresis in the null or deadband region of the valve was noted for each addition of artificial contaminant and shown in Fig. 4. The initial cleanliness of the fluid in the calibration test system is not known before contamination is added; therefore, the value of hysteresis in theoretically clean fluid must be placed on the curve with respect to the added contaminant. (Theoretically clean fluid is defined as a particular fluid condition with respect to contamination that has no observable effect on servo-valve performance.) The curve of Fig. 4 may be adjusted for the theoretically clean fluid in the following manner:

(1) Determine the amount of inherent hysteresis in the valve apart from contamination effects on the slide and sleeve. This may be accomplished by conducting a number of deadband hysteresis tests in a hydraulic system to which contamination has not been added and that has been filtered for extensive periods of time with effective filters. These tests should be conducted with the return pressure orifice removed from the valve (maximum slide positioning pressure per unit input current).

(2) Extrapolate the calibration curve of Fig. 4 at the lower end down to the value of deadband hysteresis equal to that in the clean fluid tests.

(3) Adjust the calibration curve so that the point of theoretically clean fluid corresponds to zero contamination added.

Determination of safe contamination levels

The amount of artificial contaminant that a normal system valve can tolerate can be noted from Fig. 4. It is based on deadband hysteresis limits established by the servo system design and performance requirements. At this level of contaminant the servo-valve contamination meter reading can be noted that will represent servo-valve failure level. Because of the erratic nature of contamination and the possibility of rapid increases, a safe operating level should be established at a value well below the failure level. A suggested safe operating level would be the level of contaminant that causes the servo-valve contamination meter to exceed the performance requirements for the system.

The calibration curve of Fig. 4 is based on a particular known size, material, shape, and weight of contamination, while that in a system woud probably be different under various operating conditions. Since the servo-valve contamination meter is sensitive to contamination in the same manner as the valves in the system and a correlation between them has been noted from Fig. 4, the meter measurement is seen to be independent of the type of contaminant. The meter will measure effects of contamination, which is of prime importance with respect to system performance.

Meter location in the system

To determine the proper location in a hydraulic system of the proposed servo-valve contamination meter, the sources of possible contamination must be considered. If the components that might wear and contribute to contamination were located up-stream of the system servo valves, then the meter should be located where the fluid goes into the valve. This is usually the case in a valve test stand.

In actual missile or airplane operation, however, the meter location can become complicated by contamination generating components being located in branch lines or even between servo-valve load pressure ports. The ideal location for a contamination meter would then be down-stream of the system servo valves or in the return to the reservoir. This would be impossible, however, since the servo-valve contamination meter requires system supply pressure for satisfactory operation. The location of the meter, therefore, must be at the next point in the system that will provide supply pressure, or at the pump outlet up-stream from the system filter.

Missile tests

The servo-valve contamination meter was installed in a test bench, along with another type of servo valve. The test bench was attached to the missile hydraulic system. Oil samples were taken periodically for gravimetric and Tyndall effect measurements of the contamination level. The tests were conducted with and without system filtration for periods of time to observe changes in contamination level.

The contamination levels were unusually high when measured by the gravimetric and Tyndall effect methods while, except for a few high readings, the contamination level on the servo-valve contamination meter indicated only slight increases. The missile surface operation indicated normal control.

By cycling each servo actuator in the hydraulic system separately for a time, following with servo-valve contamination meter readings, the location and amount of contamination generated could be determined. In the particular missile tested the actuator system farthest from the pump was found occasionally to have about 20 times normal amounts of contamination. This suggests that contamination from the system had been settling out in the long lines going to the front of the missile. During high-flow operating conditions on the forward system the hydraulic fluid picked up the contamination again and carried it to other parts in the system.

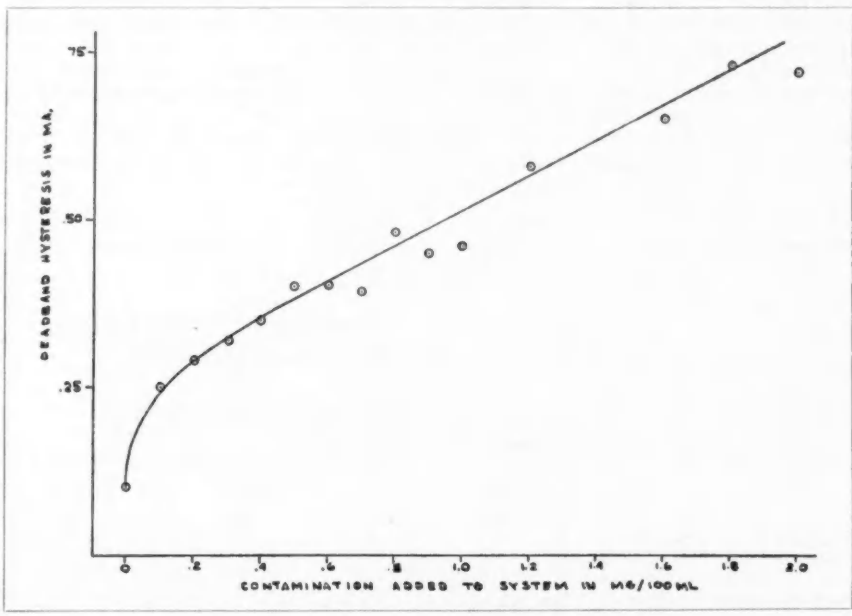

Fig. 4 — Calibration curve of servo-valve contamination meter.

Fatigue Testing—

Based on paper by

R. F. Griswold

Chrysler Corp.

CHRYSLER uses fatigue tests and statistical analyses for determining the quality of front suspension torsion bar springs.

Many steels have enough hardenability and static strength to make them economically practical as front suspension torsion bar springs. All of these can be forged and machined. All can be austenized and quenched to equivalent martensitic structures. And, all can be tempered to a common hardness. How, then, can we select the steel which will give optimum quality? One way is through the use of specimen fatigue tests using composition as the only variable.

Consider the tests run by Chrysler on two experimental heats of steel as part of a program aimed at developing a low cost, high hardenability steel suitable for torsion bar springs. The heats were cast as big-end-up ingots 3 in. square and were identified as heats CM 3204 and CM 3207. The ingot molds were designed for 30-lb heats, and extra large hot tops were used. Both heats were cropped, forged to 2 in. diameter bars, and then turned to 1¾ in. diameter to remove all surface defects. The machined bars were hot rolled to ⅝ in. diameter, and a sample from each heat was analyzed chemically (Table 1). After the chemical analyses, the bar stock was exposed to complete magnaflux inspection. No material defects were revealed, and the bars were processed for rotating beam fatigue tests as follows:

1. Anneal bar stock at 1550 F, cut into 4 in. lengths and identify each 4 in. length by the proper heat number.

2. Rough machine the 4 in. lengths into R. R. Moore fatigue specimens.

3. Dense copper-plate the rough-machined specimens to prevent decarburization during heat treatment.

4. Austenitize the rough machined specimens at 1515 ± 10 F and quench them on rotating rollers which are flooded with oil.

5. Pretemper the rough-machined specimens at 375 ± 25 F and temper them to a hardness of 50 Rockwell C throughout, as shown in Table 2.

6. Finish-grind the specimens and superfinish them to a surface finish of 0–2 microin.

The resulting specimens were fatigue tested at several levels of stress on 10,000 rpm R. R. Moore rotating beam machines until either failure occurred or 100 million cycles of stress had been endured. The test results of five specimens from each heat are shown in Fig. 1.

Actually 35 specimens from each heat were tested. However, if only five specimens from each heat had been tested, they could have been the specimens which yielded the results shown in Fig. 1. This would have led to the conclusion that the chemical

Table 1 — Chemical Analysis of Two Experimental Steels

Element	Heat CM 3204	Heat CM 3207
Carbon, %	0.68	0.68
Manganese, %	0.85	0.83
Phosphorus, %	0.022	0.025
Sulphur, %	0.02	0.02
Silicon, %	0.24	0.26
Chromium, %	0.09	0.40
Nickel, %	0.04	0.03
Molybdenum, %	0.37	0.24

Table 2 — Tempering and Hardness Data for Two Experimental Steels

Heat Number	Tempering Temperature — F	Tempering Time — hr	Specimen Hardness — Rockwell C		
			Minimum	Maximum	Average
CM 3204	700	1	49.5	50.3	49.9
CM 3207	725	1	49.4	50.0	49.7

A New Way to Get Quality

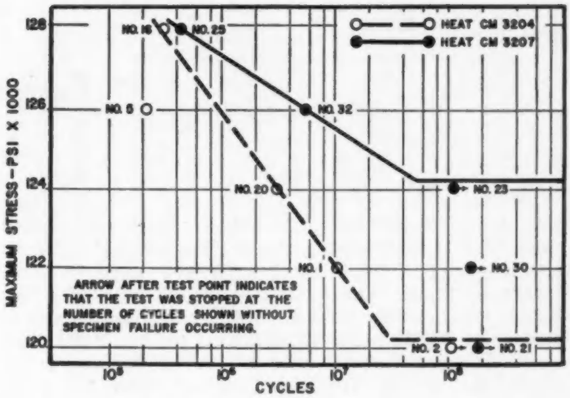

Fig. 1 — Fatigue test results of five specimens from each of two experimental heats of steel.

composition of heat CM 3207, rather than that of heat CM 3204, would promote optimum material quality.

The relatively large number of specimens that were tested from each heat allowed a scientifically planned program to be conducted. The program was carried out in accordance with the statistical method developed for determining the sensitivity of explosives.

The specimens from each heat of steel were fatigue tested sequentially on a single machine. The first specimen from each heat was tested at a stress level estimated as the stress at which 50% of the specimens might survive 100 million test cycles. Each remaining specimen from each heat was tested at a stress level determined by the test results of the preceding specimen from the same heat. If the preceding specimen failed, the test stress was lowered 2000 psi; if the preceding specimen endured 100 million test cycles, the test stress was raised 2000 psi. The results were recorded as shown in Fig. 2 and these data were analyzed statistically to obtain the mean fatigue limit of each group of specimens.

The mean fatigue limit is the stress at which there is an even chance of a specimen failing or enduring 100 million cycles. In calculating the mean fatigue limit, the event which occurs the fewest number of times is used. As shown in Fig. 2, 16 failures and 19 "runouts" were obtained with the CM 3204 specimens. Therefore, for this heat, "failure" was the event used and the data were tabulated as shown in Table 3. In this table, column *ST* gives the stress levels at which one or more failures occurred; i is an assigned number — always starting with zero for the lowest stress at which the least frequent event occurred; n_i is the number of least frequent events occurring at each stress level; and in_i is the product of i and n_i.

The mean fatigue limit is calculated by means of the formula given at the bottom of Table 3 where m is mean fatigue limit; d is the interval between stress levels — 2000 psi in this case; A is the sum of in_i; and N is the total number of least frequent events. The plus sign in the formula is used when "runout" is the least frequent event and the minus sign is used when "failure" is the least frequent event.

As Table 3 shows, a mean fatigue limit of 124,626 psi was obtained for heat CM 3204. Similar calculations yielded a mean fatigue limit of 121,626 psi for heat CM 3207.

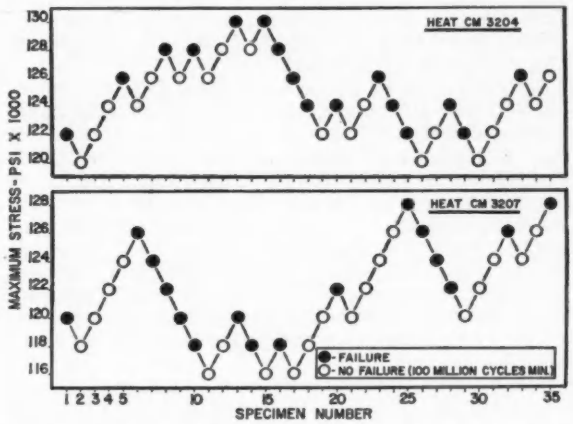

Fig. 2 — Sequential fatigue test results of two experimental heats of steel.

Additional statistical calculations were performed for each heat to obtain an estimate of the stress at which 99% of the specimens might be likely to endure 100 million cycles. Calculations for heat CM 3204 showed the mean fatigue limit to be 111,993 psi. Similar calculations for heat CM 3207 yielded a stress of 100,143 psi. Thus the mean fatigue limit and 99% fatigue limit values obtained for heat CM 3204 were higher than for heat CM 3207 and refute the unsound conclusion implied by Fig. 1.

The same statistical method was used to compare two steels whose use has been more conventional in suspension applications — AISI 5160 and AISI 9260. R. R. Moore rotating beam fatigue specimens were employed again and specimens from a single heat of each steel were fabricated using the procedure previously described. A hardness of 50 Rockwell C was obtained by tempering the 5160 at 725 F and the 9260 at 800 F.

In this program, 50 specimens from each heat of

steel were fatigue tested to obtain statistical results even more reliable than those obtained with the 35 specimens per heat used with the experimental steels. A mean fatigue limit of 87,640 psi and a fatigue limit (99% runout stress or 1% breakage stress) of 77,933 psi were obtained for the AISI 9260 steel. A mean fatigue limit of 120,166 psi and a fatigue limit of 103,742 psi were obtained for the AISI 5160 steel (Fig. 3).

These results were used for further statistical analyses to obtain 99% confidence intervals for the mean fatigue limit of each steel (Fig. 4). This means that the true value of mean fatigue limit for each steel will lie wthin its interval 99% of the time. Since 99% is a high level of confidence and since the intervals do not overlap (Fig. 4), it can be concluded that the AISI 5160 steel tested is superior to the AISI 9260 steel tested.

Microstructures of specimens of both steels showed that they were properly and similarly hardened. Grover, Gordon, and Jackson[1] state that ". . . the fatigue properties of the widely used steels are relatively insensitive to composition, somewhat dependent on metallurgical structure for a particular hardness, and very approximately directly proportional to the hardness." The two steels in question had essentially the same carbon content, hardness, and microstructure. However, Grover, Gordon, and Jackson also assert that these trends ". . . may be offset, in a particular instance, by other factors such as . . . inclusions. . . ." Consequently, to determine whether a difference in metallurgical "notches" might be reflected in the results, "dirt ratings" were obtained for both steels. The results showed the two steels to be comparable in this respect. Apparently, a scientifically conducted fatigue testing program revealed a quality difference which would, otherwise, have gone undetected and unsuspected.

Specimen fatigue tests are valuable in determining, not only the effect of chemical composition on quality, but also the effect of other single factors on quality, since the results obtained are independent of design and the variables inherent in manufacturing production parts. For example, three groups of R. R. Moore rotating beam fatigue specimens which had been fabricated from a single heat of AISI 5160 steel were austenitized and quenched to a through-hardened, 100% martensitic structure, but each group was tempered at a different temperature. As a result, each group of specimens had a different hardness — namely, 45, 50, and 55 Rockwell C.

To obtain fatigue strength comparisons at a relatively long life, 30 specimens per group were fatigue tested, as before, until either failure occurred or a life of 50 million cycles had been endured. Estimates of mean fatigue strength at a life of 50 million cycles and 99% confidence intervals for these estimates were then calculated for each group as before. These results are shown in Fig. 5. They show that there is no significant difference between the 45 and 55 Rockwell C groups, but that the 50 Rockwell C group is significantly better than either of the two other groups.

[1] Grover, H. J., Gordon, S. A., and Jackson, L. R., The Fatigue of Metals and Structures, U. S. Government Printing Office, 1954, page 160.

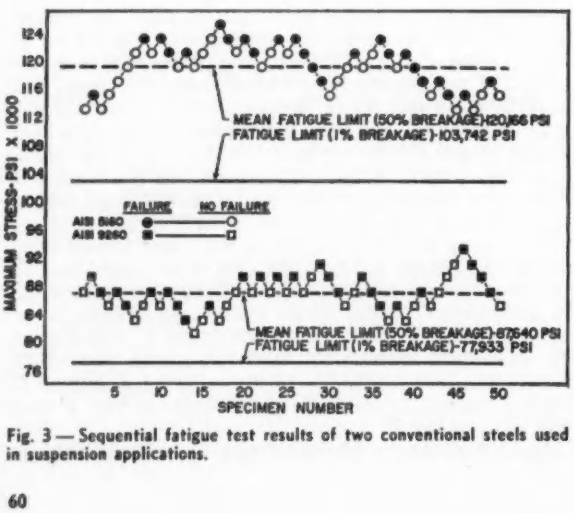

Fig. 3 — Sequential fatigue test results of two conventional steels used in suspension applications.

Table 3 — Calculation of Mean Fatigue Limit

ST	i	n_i	in_i
130,000	4	2	8
128,000	3	3	9
126,000	2	4	8
124,000	1	4	4
122,000	0	3	0
		$N = 16$	$A = 29$

$$m = \text{lowest ST} + d\left(\frac{A}{N} \pm \frac{1}{2}\right)$$

$$= 122{,}000 + 2{,}000\left(\frac{29}{16} - \frac{1}{2}\right) = 124{,}626 \text{ psi}$$

The testing programs which have been discussed were instrumental in establishing material and heat treating standards for the production of Chrysler's front suspension torsion bar springs. AISI 5160 steel, with certain minimum hardenability requirements, and a martensitic structure, tempered to a nominal hardness of 50 Rockwell C, is specified for the springs.

Production Testing

Continuous fatigue testing of production bars, selected at random, is one of the means employed to control and maintain production quality. Individual operations in the torsion bar fabricating procedure are also evaluated constantly.

The fatigue testing of specimens is an important part of this quality control. For example, torsional fatigue specimens of spring steel are ground and heat treated under closely controlled laboratory conditions. These specimens are then placed in a fixture which allows them to be shot peened along with production bars. Life test results obtained with these specimens, arc height and coverage readings on Almen strips, analysis of production shot samples, and fatigue test results and coverage readings on production bars are all utilized in maintaining optimum benefits from the shot peening operation.

Fatigue testing has been valuable to production quality control in other respects. In one instance, replacement rollers of questionable quality were received for a torsion bar production quenching machine. The rollers were used in the fabrication of a group of test bars but were withheld from production use. Fatigue test results obtained with the test bars were substantially lower than normal results for bars of this part number.

Furthermore, inspection of the life-tested bars showed that 70% of the failure origins were located at small surface indentations resulting from imperfections on the surfaces of the rollers. Consequently, these rollers were rejected. Also, a quality control procedure was instituted to insure against the production of bars at any time on quenching machine rollers of questionable surface quality.

Many other examples of the determination of the quality of automotive front suspension torsion bar springs through fatigue testing could be given in detail. These would include:

1. Fatigue tests to evaluate new forging dies.
2. Fatigue tests to evaluate special shot peening procedures.
3. Fatigue tests to evaluate experimental heat treating conditions.
4. Fatigue tests to evaluate proposed design changes for future automobile models.

However, it is hoped that the detailed examples which have been given are of sufficient scope to illustrate the value of scientifically conducted fatigue testing programs in the determination of quality.

To Order Paper No. 32S ...
... on which this article is based, turn to page 6.

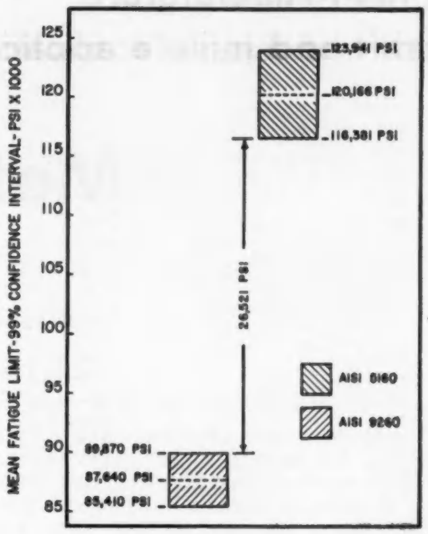

Fig. 4 — 99% confidence intervals for the mean fatigue limit of each of two conventional steels used for suspension application.

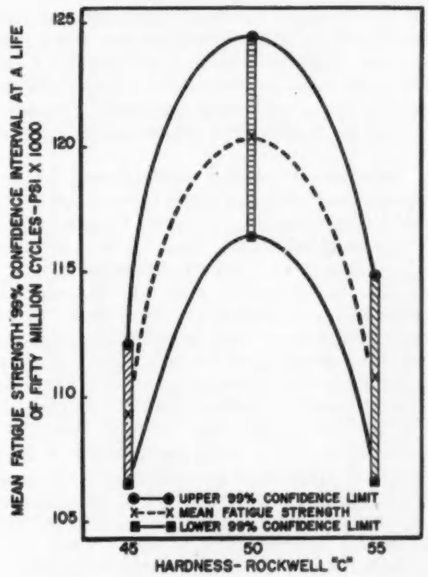

Fig. 5 — Mean fatigue strength at a life of 50 million cycles and 99% confidence intervals for AISI 5160 steel of Rockwell C hardness 45, 50, and 55.

For high-temperature aircraft and missile applications ...

Metal Hydraulic Seals

Based on paper by

C. E. Hamlin

Autonetics, Division of North American Aviation, Inc.

METAL seals, as a class, appear to have the greatest potential for sealing in pressures in extreme temperature environments and they may be a vital necessity in areas of nuclear irradiation. They are inherently more tolerant of high temperatures, thermal cycling, and pressures than the elastomers, but far more difficult to design.

piston seals

The piston seals under investigation at Autonetics are pressure energized and have an initial interference between the seal lip and the cylinder bore. An example is shown in Fig. 1. Determination of the optimum initial interference is difficult. Such interference for a given seal configuration must often be predicated upon a compromise between breakout friction and life-leakage requirements. Tests indicate that seals with high breakout friction will allow minimum leakage for a comparatively few cycles, while seals with low breakout friction tend to leak slightly more, but have much greater life expectancy.

When lubricated metals are placed in contact under an applied load, a plastic flow of the metal occurs until the actual contact area is large enough to support the applied load. This deformation causes a film of lubricant to be trapped between the metal surfaces, and the pressure will not be uniform over the entire region of contact. In regions where the pressure is highest, a local breakdown of the lubricant film may occur and result in metal adhesion.

Tests indicate that dynamic metal seals with a surface hardness lower than that of the mating surface last longer under 500 F than seals having harder surfaces. The best results have been obtained with ductile iron (meehanite) seals against a nitrided nitralloy cylinder bore. Metal seals of the lip type have been operated in excess of 10,000 cycles in an oil temperature of 500 F with a leakage rate not exceeding 1 cc per thousand cycles.

shaft seals

Sealing the piston shaft on an aircraft hydraulic actuator is one of the most difficult problems. The shaft seals must hold leakage to an absolute minimum since any leakage of fluid creates two hazards. If the fluid enters a very hot compartment it may ignite; if the flow is copious it could deplete the system fluid supply. In both cases it could mean the loss of the aircraft.

Autonetics is developing a 700 F hydraulic system, one requirement of which is the operating of seals for 50,000 cycles at temperature. Tests for this project used an actuator with a double-ended piston so that two shaft seals could be tested simultaneously, (Fig. 2). Furthermore, the actuator was so designed that leakage flow past each shaft seal could be collected and measured. The end glands can be adapted to accommodate various seal configurations. Test seals, as shown in Fig. 3, were fabricated from ductile iron. They are pressure energized and an initial interference is used to insure low pressure sealing.

Six sets of these seals were tested at room temperature and the same number at 500 F. Rectilinear motion was used so that no side loadings would be imposed upon the seal. Five sets ran for 100,000 cycles at room temperature with an average total leakage of approximately 3 cc. The sixth set, tested at room temperature ran for 700,000 cycles with a total leakage of 5 cc.

high-temperature tests

The seal test actuator was installed in an oven for tests at elevated temperatures, with all other operating conditions identical with those in the room temperature tests. A seal was considered to have failed when the leakage rate exceeded 1/25 of a drop per cycle, which rate concurs with the requirements of paragraph 4.5.4 of specification MIL-C-5503B.

Of the six sets of seals tested at 500 F, 70% operated in a satisfactory manner for 55,000 cycles or better, while 30% operated for 90,000 cycles or better. The first indication of leakage usually appeared between 15,000 and 20,000 cycles. Seal failure was invariably caused by loss of interference between the seal and the shaft; loss of interference of the faying surfaces was caused by wear. Some deformation of the seal always occurred because of unavoidable angular misalignment between the two seals when installed in opposite ends of the test actuator. From this it appears that metallic seals can be equal to, or better than, the elastomeric O-ring under certain conditions.

Three sets of seals tested under side load condi-

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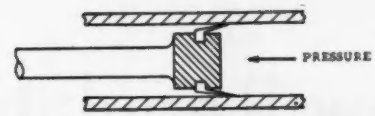

Fig. 1 — Type of metallic piston seal under investigation. It is pressure energized and has an initial interference between seal lip and cylinder bore.

tions showed an average life of only 5000 cycles. From this it is concluded that seals cannot be expected to carry loads normal to their operating axis. Further testing will be done using load carrying bearings outboard of each seal.

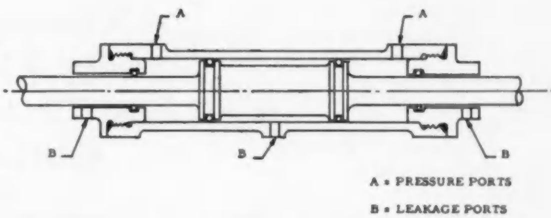

Fig. 2 — Seal test actuator with double-ended piston designed to permit collection and measurement of leakage flow past each of two shaft seals.

static seals

We have developed a metallic static boss seal, for use under either AN unions or universal fittings, which virtually eliminates static leakage even under the most severe conditions of temperature and pressure. It fits into a standard AND 10050 boss and requires no presetting. Fig. 4 shows the seal properly installed on a universal fitting before and after torque is applied to the nut. The inside diameter of the rim of the seal is in contact with the neck of the fitting forming an effective seal. The AN 924 nut is generally used, but the AN 6289 nut can be used, provided the recessed side of the nut is away from the seal.

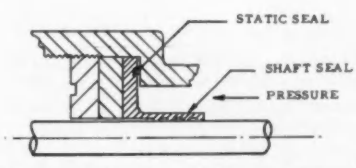

Fig. 3 — Ductile iron shaft seals of Autonetic design. Of six sets of seals tested at 500 F, 70% performed satisfactorily for 55,000 cycles or better.

Boss seals made from stainless steel, Inconel X, and aluminum have shown the ability to remain leakproof at temperatures from –360 to 1000 F, and at pressures of 5–10,000 psi. During test the following liquids and gases were used as the pressure medium:

1. Silicate esters.
2. MIL-O-5606.
3. Liquid oxygen.
4. Liquid nitrogen.
5. Helium.
6. Dry nitrogen.
7. Anhydrous ammonia.
8. Water.
9. Air.

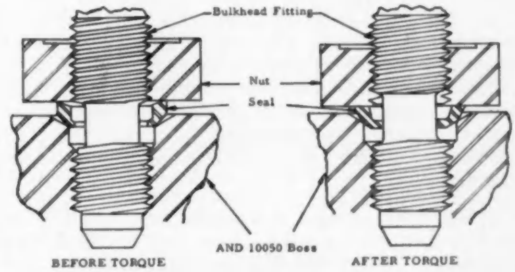

Fig. 4 — Natorq metallic boss seal installed on universal fitting, shown before and after torque application to nut.

The seal becomes an integral part of the fitting when torque is applied, yet repeated assembly and disassembly of the fitting-seal combination does not degrade sealing integrity. Moreover, these seals can tolerate rather high discrepancies of tolerance on both fitting and cavity dimensions without adverse effect on their sealing ability. They are now known commercially as "Natorq" boss seals.

To Order Paper No. 50S . . .
. . . on which this article is based, turn to page 6.

Are you puzzled about the

New Regulations for Operating Jet Transports?

A member of the United States delegation to the international conference on jet transport certification discusses herewith some of the background of the new Special Regulation 422 (now revised to SR-422A) for jet aircraft. He also explains many of the terms used in it and points out some of its inconsistencies, as well as its benefits in terms of increased safety.

Excerpts from paper by

M. B. Spaulding, Jr.

Technical consultant

THERE are many differences in philosophy between SR-422A — the new regulation under which jet transports must operate — and CAR 4b — the Civil Air Regulation on airworthiness that it replaces. This is particularly true for the take-off phase, because the jet is much more sensitive to the steps and procedures followed during the take-off run.

Differences between CAR 4b and SR-422A

A. Characteristics of Take-off — In the past not too much attention was paid to details of the actual physical steps that constitute a take-off. This arose because the piston-powered airplane was not too sensitive a beast and, consequently, whether or not the nose was rotated was not of any real concern. However, with jet aircraft and swept wings, all of this has changed. It is now necessary to pay a considerable amount of attention to the various procedural steps and speeds followed during the course of the take-off run. Some of the more important of these are:

(1) V_R: This is the so-called "rotational" speed and represents an entirely new concept in take-off philosophy. When SR-422 was first adopted, it required that the airplane be accelerated "on or near the ground" until such time as speed V_2 was reached. This was in conformance with the old philosophy applied to piston-powered airplanes. The present requirement of Section 4b.116 still remains in this form. However, it was found that this concept had to be changed when it was realized that the jet aircraft accelerates very rapidly between the time that the nose is rotated and the airplane breaks from the ground until the time that it passes through the 35-ft point. Consequently, if such a rotational concept was not included, the airspeed of the accelerating jet aircraft would overshoot the value that had been established as V_2. This was but the first of several changes required when a detailed analysis was made of the actual take-off procedure.

(2) V_2: Under CAR 4b, V_2 was the minimum take-off safety speed, that is, the minimum speed at which the airplane could break from the ground and start its climb. Nowadays under SR-422A, V_2 is simply a speed reached prior to the time that the airplane attains a height of 35 ft. At the same time, it is limited by climb requirements so that the actual value of V_2 must always be greater than V_R. Its relationship with the stalling speed and the minimum control speed remains the same as it has always been. It is true that the Board continues to call V_2 the minimum take-off safety speed, but there have been interposed between what used to be called V_1 and V_2 several new speeds: namely, V_R, the rotational speed, and now more recently the minimum unstick speed. Actually, V_2 is now nothing but a minimum climb speed, that is, it is the minimum speed at which the applicant for a type certificate can show the ability to meet the climb requirements specified for the one-engine inoperative condition.

(3) V_{MC}: This is still basically the same minimum control speed that has always been specified in the Regulations. In the most recent changes proposed to SR-422A, the Board contemplates eliminating the requirement that V_{MC} should not exceed 1.2 times

the stalling speed. In other words, this speed restriction is not contained in the latest proposals.

(4) V_{MU}: This new concept of a minimum unstick speed is, at the present moment, contained, in spirit, in SR-422A in paragraph 4T-114(c)(4). Here the Board states that V_R shall not be less than "a speed equal to 110% of the minimum speed above which the airplane, with all engines operating, can be made to lift off the ground and to continue the take-off without displaying any hazardous characteristics." In other words, under this new concept V_{MU} has replaced the old V_2. Also, in the latest proposed changes, the Board has added a still further requirement, in that it has proposed that V_R shall not be less than 105% of the single-engine minimum unstick speed nor 110% of the all-engine minimum unstick speed. Thus, there will be *two* minimum unstick speeds, all of which further add to the confusion.

(5) All Engines versus One Engine Out — When the Board revised the original SR-422 into SR-422A it saw fit to include in the take-off distance a requirement that the all-engine take-off distance also had to be taken into account in determining the actual runway length required, and hence the maximum allowable take-off gross weight. This again was a completely new concept, and one that was borrowed from the British regulations. Actually, the British started out originally by specifying only an all-engine operating take-off requirement. It wasn't until a subsequent date that they included the one-engine-inoperative requirement as a possible controlling factor.

B. Unbalanced Field Length — With the advent of of SR-422A, the concepts of "clearway" and "stopway" were brought to the front in the take-off regime.

(1) Clearway: A clearway is simply "an area beyond the airport runway not less than 300 ft on either side of the extended centerline of the runway, at an elevation no higher than the elevation at the end of the runway, clear of all fixed obstacles, and under the control of the airport authorities." This area can be used to extend the take-off distance available and, consequently, to increase the maximum allowable take-off gross weight from the runway of an airport. However, its use without an associated stopway area results in the use of unbalanced field lengths, that is, the distance to accelerate and stop is not the same as the distance to take-off. Consequently, its use can confuse operating techniques in the cockpit in that two different V_1's would have to be used by the pilot, that is, one for accelerate-stop, and one to go.

(2) Stopway: The latest changes have brought back the concept of the balanced field length (except where the take-off is over water) by allowing a stopway, which is defined as, "A rectangular area beyond the airport runway centrally located about the extended centerline of the runway, not less in width than the width of the runway, and designated by the airport authorities for use in an aborted take-off, such area being capable of supporting the airplane when so used without inducing structural damage to the airplane." This will also allow the air carrier to increase the take-off gross weight by taking advantage of the stopway distance.

C. Gradient Concept of Climb — Cook and Weaver[1] originally recommended that all climb performance requirements be stated in terms of a gradient of climb. In this way, it was considered that airplanes with high wing loadings and consequently high stalling speeds would not be penalized as severely as they are under the old "stall speed squared" law. At the same time, since a gradient is nothing but an angle of climb, and not a rate of climb, it would mean that all airplanes of relatively the same size or type would be operating at the same level of safety, in that each would have to have the same angle of climb. For this and other reasons, the Board felt in adopting SR-422 that the gradient concept should be incorporated in these requirements.

It would undoubtedly be admitted by CAB personnel responsible for the promulgation of SR-422 that some of the gradient climb values originally used left something to be desired. As a matter of fact, it is interesting to examine the values of the various climb gradients that have been proposed or adopted throughout the life of SR-422. Almost universally, these values have been decreased from those originally proposed. These decreases have been brought about at the request of both the manufacturers and the airlines as the result of examining the application of the values to actual operating conditions.

This gradient concept, of course, is included not only in the take-off requirements but is also found in the en route requirements. It is believed that in the operation of jet aircraft the values stated are not too restrictive, and that the gross weights that they allow will permit economical operation.

D. Vertical Clearance — Another major difference that appears in SR-422A is the fact that the vertical clearance required has been reduced from 50 ft to 35 ft. It was a compromise that was accepted by all parties on the basis that under CAR 4b there is only 50% temperature accountability, whereas under SR-422A, there would be full temperature accountability. Consequently, it was felt that in day-to-day operations 35 ft with full temperature accountability was the equivalent of 50 ft with one-half temperature accountability.

E. Full Temperature Accountability — As one person has stated it, full temperature accountability had to be instituted in order to avoid another Civil War. This war could arise because people in the North could travel more safely than those in the South. Hence, it was agreed that, under SR-422, full temperature accountability should be applied to the performance requirements throughout the flight regime. However, it is interesting to note that temperature accountability has not been applied to the landing configuration. Presumably, this arises because of the fact that the landing distance, that is,

[1] "Derivation of Airworthiness Performance Climb Standard," by F. G. R. Cook and A. K. Weaver of the United Kingdom. Paper No. 6078-AIR/514, presented at ICAO Meeting, 1950.

New Regulations for Operating Jet Transports

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60% of the available distance, represents a rather conservative approach and, consequently, temperature accountability is not required.

F. Increasing Clearance with Distance Traveled from End of Runway — At present, SR-422A requires an increasing clearance from the point of attaining 35 ft up to the point where the airplane achieves an altitude of 1500 ft above the take-off surface. The latest proposed changes would also apply this same kind of increasing clearance philosophy to the horizontal clearance for obstacles that are less than 5000 ft away from the flight path. The increasing clearance concept is one that has been contained in the British Regulations for some time but is new as far as the U. S. Regulations are concerned.

Problems with SR-422 and SR-422A

As is always the case with any regulation, during the course of its development, it was discovered that words, as such, mean many things to many people. For instance, in SR-422 as originally promulgated, the airplane was to be accelerated "on or near the ground" to speed V_2 during which time the critical engine was to be made inoperative at speed V_1. The CAB and the CAA personnel considered that this meant not more than 18 in. or 2 ft off the ground. On the other hand, the aircraft manufacturers considered that when an airplane had reached a height of 35 ft, it was still "on or near the ground." It was for this reason that, in an effort to clarify the situation, it was necessary to institute the system of rotational speeds and minimum unstick speeds. Other problems that have arisen are:

A. Inconsistencies in Configuration, Weight, and Power — In the original SR-422, in determining the take-off climb requirements, the CAB included a requirement that the power was to be that at the time that the gear was fully retracted, while the weight was to be that at the time when the retraction of the landing gear was initiated. This of course created a lot of confusion and a great deal of difficulty on the part of the manufacturers. This has been eliminated in SR-422A.

B. Variations in Weight along the Take-off Path — In the past, the Civil Air Regulations have always been quite specific as to the weight that was to be applicable at any particular time during the take-off. When Draft Release 56-20 was originally issued, the Board indicated that it would be permissible to reduce the weight of the airplane during the course of the take-off, since, as is well known, a jet engine consumes large quantities of fuel and consequently there are large reductions in weight. However, this item, as a specific reference, has disappeared completely from both SR-422 and SR-422A. Presumably, it can be read into SR-422A that such a procedure is permissible, but at present it is not clear.

C. Runway Length to Be Controlling — Under the old CAR 4b, the take-off path was simply a requirement on the part of the manufacturer to determine the actual take-off distance under varying conditions and for varying gross weights. There was no requirement in CAR 4b indicating that the airplane had to reach a height of 50 ft at any particular point during the take-off.

The 50-ft requirement is included in CAR's 40, 41, and 42. An examination of these parts indicates that they contain inconsistencies in the wording used. Presumably, this has never caused much difficulty in the past, but actually CAR 40 states that a height of 50 ft must be reached "before passing over the end of the runway," while CAR's 41 and 42 indicate that the height of 50 ft does not have to be reached until "passing over the end of the take-off area," or presumably the fence at the boundary of the airport. At present SR-422A does not require that a height of 35 ft be reached before passing over the end of the runway or even the boundary of the take-off area. Apparently, however, the Board intends to try to correct this situation since, in Draft Release 58-1C, it is proposed that the take-off run cannot exceed the length of the runway. It would appear that, if an approved clearway and stopway are included as part of the approved take-off area, then it should be possible to drag the airplane wheels to the end of the paved runway before lifting off. It would then be possible to use the clearway and stopway to their full beneficial effect. Actually, it is anticipated that for some time not many commercial operators will take advantage of the permission granted by the Board in connection with either a clearway or a stopway. Even so they should not be prevented from using them to their fullest advantage.

D. Approach Operational Requirements — At present, SR-422A simply states as a performance requirement that the approach climb speed shall meet certain specified values. But, contrary to the British regulations the operating rules do not contain a requirement applying this approach climb requirement. In other words, there is no requirement existing in SR-422A that, in making an approach for a landing, the approach must be made at a specified speed or in any specified condition. Consequently, it would appear that this approach requirement, which is a carry-over from the old DC-3 days, should be either eliminated or brought up to date.

E. Shift in Decision Speed Point — In the operation of jet aircraft, the decision speed (V_1) point has been shifted radically toward the take-off end of the runway. This is clearly demonstrated in Fig. 1, which showing the relationship between take-off distance and attainment of various speeds, on the one hand, and height achieved, on the other hand, for both a piston-powered and a jet aircraft. This problem arises because of the fact that the power for

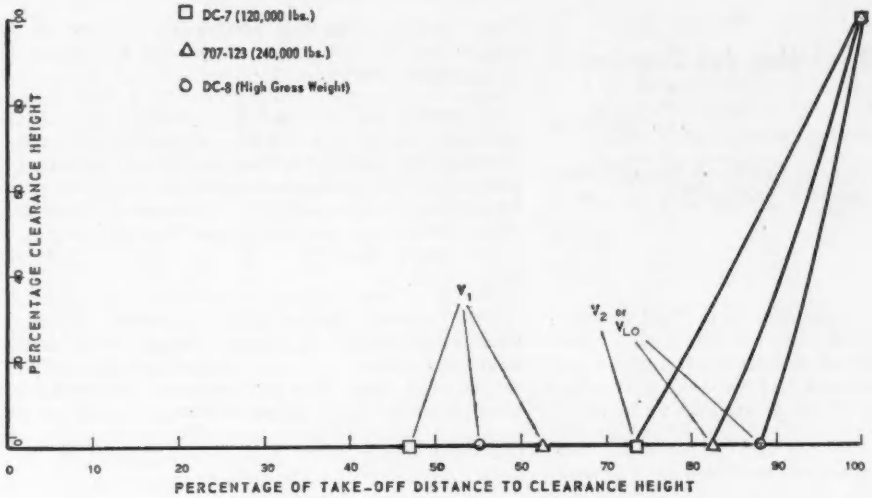
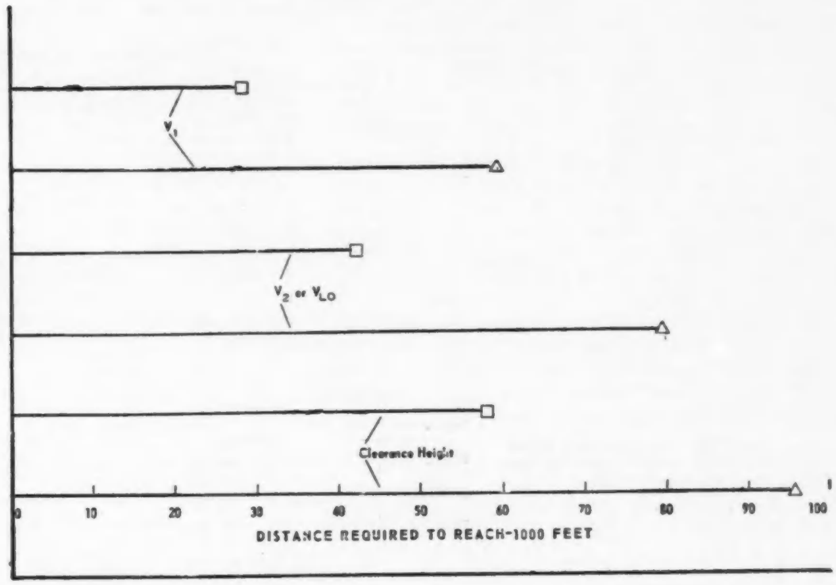
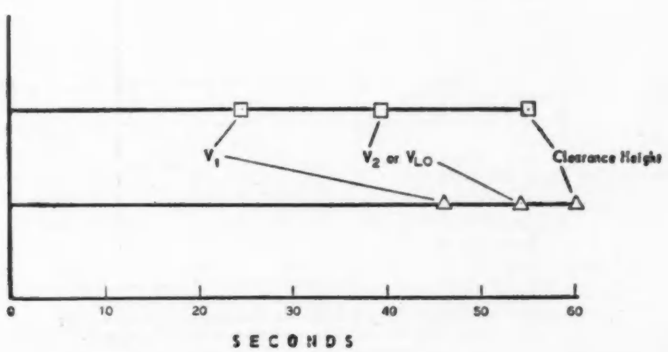


Fig. 1 — Relationship between take-off distance and attainment of various speeds, on the one hand, and height achieved, on the other hand, for both piston-powered and jet aircraft.





New Regulations for Operating Jet Transports

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acceleration of jet aircraft depends on the airspeed of that aircraft and hence it accelerates slowly at low air speeds.

Effect of SR-422A

A study of SR-422A leads one to certain conclusions. First, there is confusion in the terms used. Secondly, SR-422A, because it includes the operating rules, covers more than just the take-off and landing requirements. Thirdly, it is unclear as to what, if any, compulsion there is on an airline to operate in accordance with SR-422A.

A. Confusion in Use of Terms — There does not appear to be any clear definition of some of the terms used, for example:

(1) Minimum Unstick Speed: The manufacturer will have to determine two separate minimum unstick speeds — one for the all-engine operating condition and another for the one-engine inoperative condition. Hence, when two persons discuss the use of a "minimum unstick speed," it is essential that they realize that there are two different values of this speed.

(2) Take-off Path versus Take-off Flight Path versus Net Take-off Flight Path: These terms all sound so alike that, it is quite easy to confuse the portion of the take-off regime being discussed. Probably the use of different terms for these differ-

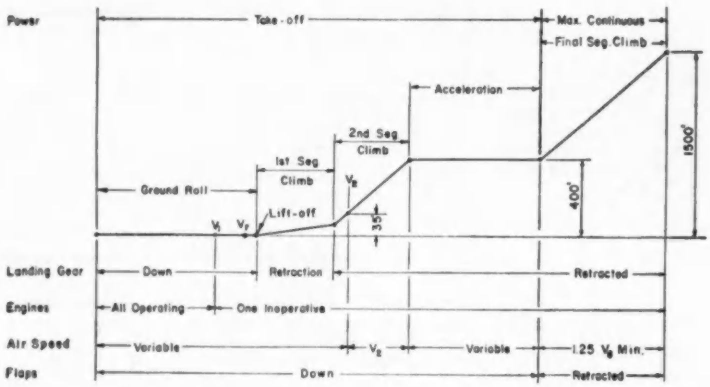
TAKE-OFF PATH

The take-off path extends from the standing start to a point where a height of 1500 feet above take-off surface is reached.

TAKE-OFF FLIGHT PATH

The take-off flight path begins at end of the take-off distance, i.e., a point 35 feet above surface, and ends at 1500 feet, or the en route altitude.

Fig. 2 — CAA chart depicting take-off path as outlined in SR-422A.



Configuration	1st T/O Segment	2nd T/O Segment	Transition (Acceleration)	Final T/O Segm.
* Required Twins / Fours	Positive / 0.5%	2.5% / 3.0%	Positive / Positive	1.2% / 1.7%
Wing Flaps	T.O.	T.O.	T.O.	Up
Landing Gear	Down	Up	Up	Up
Engines	1 out	1 out	1 out	1 out
Power	T.O.	T.O.	T.O.	MC
Air Speed	$V_r \rightarrow V_2$	V_2	$V_2 \rightarrow 1.25 V_s$	$\geq 1.25 V_s$

* Absolute Minimum Gradient Of Flight Path

MC = Max. Continuous Power

V_1 = Critical-Engine-Failure Speed

V_2 = Min. Takeoff Saftey Speed

V_s = Calibrated Stalling Speed, or min. steady flight speed at which the airplane is controllable.

V_r = Speed at which airplane can start safely raising nose wheel off surface. (Rotational Speed)

FIGURE 2

ent parts of what is actually the take-off flight path would have made them easier to understand.

(3) Take-off Run versus Take-Off Distance: A reading of the definitions of a take-off run when compared with a take-off distance is quite apt to leave one with a thoroughly confused idea of which is which. For instance, it is understood that the take-off run, by its very definition, includes the use of a clearway, yet the Board proposes in Draft Release 58-1C that the take-off run cannot exceed the length of the runway. The question comes to mind as to what happened to the clearway under this definition.

(4) Take-off Path: The wording used in SR-422A attempts to describe the various segments, or phases, comprising the take-off path. The CAA has issued a chart that it is claimed depicts the take-off path as outlined in SR-422A. A copy of this diagram is shown as Fig. 2. Note that it incorporates a horizontal segment between the second segment take-off and the final take-off phases, where this horizontal segment is marked "acceleration." It is not clear how the CAA arrived at this flight path under the wording of SR-422A.

B. Effect of Operating Rules — SR-422A includes more than just the certification requirements for take-off and landing. It also includes operating rules, which, in the past, have been included in parts of the Civil Air Regulations remote from the certification rules. The end result has been the same, but one cannot talk only of the take-off and landing requirements, since the *en route* requirements may, and quite frequently will, be controlling as to either the take-off or landing gross weights. The CAB has eliminated the all-engine climb requirement, but there still remains the requirement to be able to meet the one- and two-engine inoperative *en route* climb requirements. Over high terrain, or when operating long range, over water, these will control take-off weights.

C. Compulsion on the Operator — Is there any compulsion requiring that an airline and its pilots, who are flying equipment certificated under SR-422A, *MUST*, of necessity, comply with the operational requirements of SR-422A? Conversations with both government and industry personnel indicate quite clearly that, in their opinion, the Civil Aeronautics Board never considered that it had either the power or the desire to tell each individual pilot how he must fly each individual take-off. Apparently, the thinking was that, if the regulations were spelled out in minute detail, and then because of some unforeseen circumstance the pilot was forced to deviate ever so slightly from this flight path, he would be in violation of the regulations.

There is a lot to be said for this viewpoint, but, on the other hand, it is believed that, at the time the pilot commences the take-off with an airplane that is certificated under SR-422A, he should be told that, in order to secure the optimum performance of the airplane, he must conduct his take-off and the outgoing flight path in accordance with a very specific procedure. He should also be told that any deviation from this approved flight path can cause serious hazards. Of course, the requirements spelled out in SR-422A are all contingent upon the failure of an engine during the course of the take-off. If, as is usually the case, this engine does not fail, then it could conceivably be considered that all signals are off and the pilot is on his own to make the best take-off he can. On this point the British regulations seem superior. They require both an all-engine take-off path and a one-engine inoperative take-off path, in order to determine that there is adequate safety under either condition.

Next month . . .

. . . further discussion relating to SR-422A will be presented by Weldon E. Rhoades and Richard E. Coykendall of United Air Lines. They will cover particularly the new skills that pilots need to fly the new jets. These are required because of the new requirements in SR-422A and also because of the peculiarities of the jet transport itself.

Benefits of SR-422A

When SR-422 was first proposed, one of its best selling points was that it would raise the overall level of safety of airline transport operations. Now that it is fully effective, as SR-422A, it can be seen that this is true and that the safety of operations has benefited in the following ways.

A. Temperature Accountability — There is now full temperature accountability in all flight regimes except that of landing. Previously, there was only one-half temperature accountability, and this only in the accelerate-stop and climb-to-50-ft regimes.

B. Uniform Climb Requirements for Similar Aircraft — Under the gradient concept of climb requirements, similar aircraft will be required to meet the same climb requirement regardless of stalling speed.

C. Increasing Obstacle Clearance — As now written and proposed, the airline operator will be required to show an increasing obstacle clearance as the distance from the end of the runway increases. This is a new concept and will apply both vertically and horizontally.

D. Attainment of en Route Cruise — The flight path now extends out to 1500 ft above the take-off surface and it is required that the airplane be able to demonstrate certain minimum rates of climb in the *en route* configuration at this point. This is a new concept and plugs a loophole long existing in performance standards.

To Order Paper No. 60R . . .
. . . on which this article is based, turn to page 6.

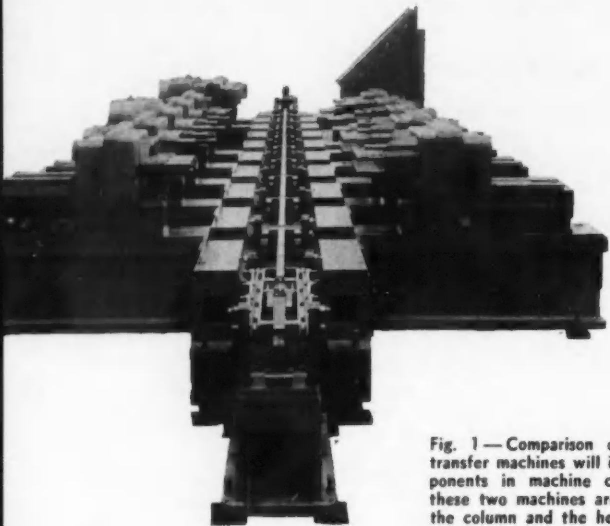
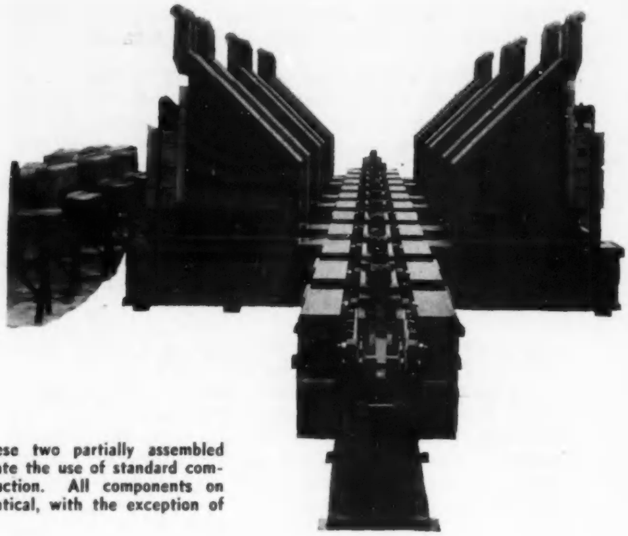



Fig. 1—Comparison of these two partially assembled transfer machines will illustrate the use of standard components in machine construction. All components on these two machines are identical, with the exception of the column and the heads.

In selecting machine tools for automatic production . . .

don't overlook . . .

• accessibility
• flexibility
• tool changing
• electrical arrangement
• work height
• identification

Based on paper by

Kurt O. Tech

The Cross Co.

FACTORS frequently overlooked in selecting machine tools for automatic production operation are flexibility, accessibility, tool changing, electrical arrangement, work height, and identification.

• flexibility

Three areas of standardization should be utilized fully to get the maximum interchangeability of machine tool parts, which really comprises "flexibility." They are:

1. Industry standardization
2. Builders standardization
3. Custom standardization

Industry standardization has been providing flexibility to industry for a number of years. It comprises standards on screws, electric motors, tool holders, machine tapers, chucks, and many other items, which have been developed by the machine tool and allied industries.

Machine tool builders standards — less widely known — provide greater interchangeability between components of machines built by different

makers. Developed by individual machine tool builders, these standards cover way-type feed units, quill-type feed units, wing bases, columns, center base sections, transfer mechanisms, and many others. The two partially completed transfer machines shown in Fig. 1 illustrate this type of standardization. All components shown on these two machines are identical, with the exception of the columns and heads.

Standardization of custom components within a specific machine is even less widely known and considered. It usually revolves around fixturing and other components directly related to the part being machined. Most commonly known standard of this type is that of part-locating pins in all fixtures throughout a transfer line. But even this standardization has been overlooked in the setting up of many lines.

Other examples of custom standards are (1) common hole patterns for mounting all fixtures on one or more transfer lines, and (2) mounting throughout a machine of designs incorporating simple bushing plates with a standard interchangeable hole pattern. These standard bushing plates permit addition of holes, the moving of holes to any station, shifting complete stations in the machine with a minimum of dis-assembly, and minimum cost where parts must be scrapped.

The use of standard bushing plates shown in Fig. 2 illustrates this custom-type standardization.

Fig. 3 illustrates many of the benefits to be derived from optimum flexibility through standardization in machine design. It shows two transmission-case lines recently installed to produce four aluminum transmission cases.

One line, designated as the Short Line, was designed to produce Transmission Case A. The other, "The Long Line," was designed to produce simultaneously all four transmission cases (A, B, C, and D) without any changes in machine setup. Sensing devices in the machine direct the flow of the various cases through the line. Where required, these sensing units actuate machine units and material-handling devices.

Since these machines were installed, two major changes in production have taken place. But both were made without affecting the production rate of either line, because the design incorporated the flexibility features just described. . . . and the custom standards were the most important of all in this instance.

• accessibility

Accessibility in machine design is the most important provision in effecting the shortest possible down-time when repairs or adjustments are necessary. Often, the allotment of slight additional floor space to provide improved accessibility will reap great rewards in machine efficiency. Machine layout *must* incorporate sufficient space between machine units for access to the center position of the machine for tool change and fixture maintenance. Many times, however, careful design and planning of location and arrangement of many semi-durable machine components will provide proper accessi-

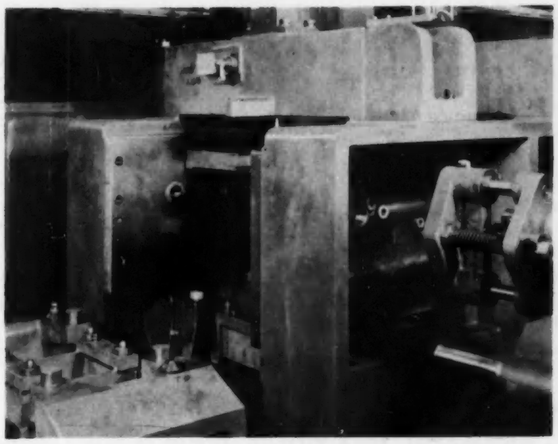


Fig. 2 — Bushing-plate construction in a transfer machine illustrates separate bushing-plate construction for interchangeability.

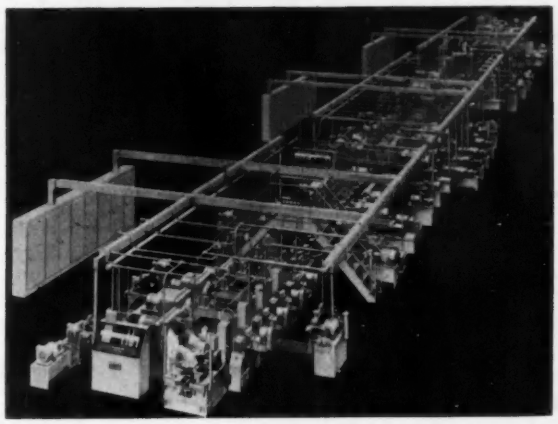


Fig. 3 — Two transmission-case lines — installed to produce four aluminum crankcases — illustrate optimum flexibility to be obtained through standardization.

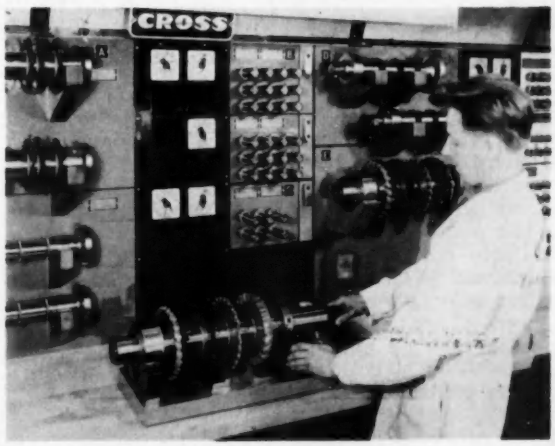


Fig. 4 — Machine-control unit with tool-setting gages.

bility without using more floor space.

Limit switches, for example, can be mounted away from contamination and easily accessible. Hydraulic control valves can be mounted away from the machine manifold or hydraulic tanks. . . . and cylinders can be removed from congested and dirty areas.

• tool changing

Adoption of quick-change, preset tooling wherever possible expedites tool changing greatly. Provision for inspection and tool setting off the machine helps, too. Ready tooling should be stored close to the machine on which it is used — with machine control units like the one shown in Fig. 4.

Tool-change systems for transfer machines must be planned, and programmed with tool-control units to have maintenance functions integrated effectively. The series of signal lights in the control units inform all maintenance personnel simultaneously of tool change periods.

• electrical arrangement

The electrical control system must satisfy certain "maintenance" requirements, because failures sometimes will occur — and must be located quickly for correction. A well-planned pushbutton console is of great importance to troubleshooting a transfer-type machine.

• work height

Comprising the work height of a machine to accommodate operator loading height or existing conveyor heights can seriously affect machine rigidity and proper machine proportions with the base elements. Space must be provided through the machine for chip conveyors, automatic lubrication systems, coolant systems, hydraulic systems, and air lines without sacrificing needed rigidity.

• identification

The information needed for a maintenance man to identify either a machine component on which he is working or its proper function does no good on the drawings in the files of the manufacturing or the plant engineering department. It must be available on the machine at the component on which trouble occurs. This can be achieved only by proper tagging on the machine, not on the component. Location of unit circuits, for instance, must be tagged outside of control cabinets, and lubrication instructions must be clearly specified directly on the machine.

To Order Paper No. 41S . . .
. . . on which this article is based, turn to page 6.

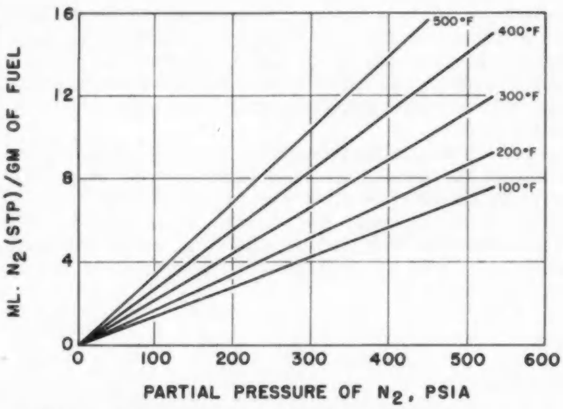
Here are the results of

Gas Solubility

Research on the solubility of gases
degassing of jet fuels at
fuel pump malfunctioning,

By A. T. Polishuk,
R. M. Kennedy,
and J. L. Jezl

Research & Development Department, Sun Oil Co.



SOLUBILITY OF NITROGEN increases with temperature at a given partial pressure in the range studied. (Data are for average of solubilities in eight JP-4 jet fuels.) At pressures greater than 500 psi, nitrogen solubilities tended to be lower than would be predicted from Henry's Law. Nitrogen does, however, follow Henry's Law more closely than oxygen or carbon dioxide ("STP" stands for "at standard temperature and pressure.")

Studies of Jet Fuels

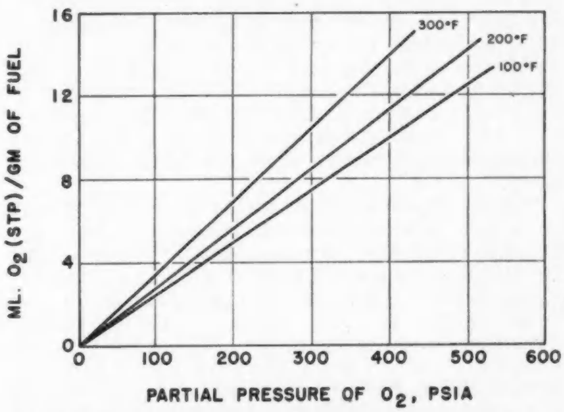
in jet fuels, such as reported here, is becoming important because extreme altitudes or high temperatures may lead to vapor lock, and even engine failure

NITROGEN, oxygen, and carbon dioxide are more soluble in JP-4 than in JP-5 jet fuels. Nitrogen is the least soluble. Oxygen is slightly more soluble than nitrogen. Carbide dioxide is by far the most soluble.

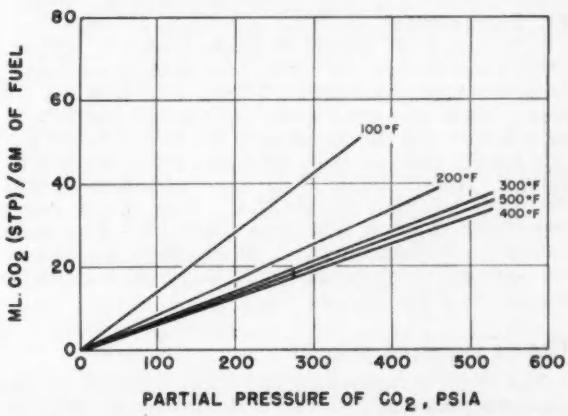
These are the conclusions of a study Sun Oil Co. made under an Air Force contract. The study covered fuels within a pressure range of 15–400 psi and a temperature range of 100–500 F. The eight JP-4 fuels studied were selected from a total of 26 JP-4 fuels to encompass the widest possible range of gravity (45.9–55.0 deg API), an aromatic range of 4–14.4%, and an average molecular weight range of 121–156. Two JP-5 fuels with an API gravity of 41.3 and 42.3 deg API were also studied.

Solubilities were determined by desorbing the gas and measuring its volume.

Here are the results obtained with the three gases:



SOLUBILITY OF OXYGEN, like that of nitrogen, increases with temperature and partial pressure. Solubility of oxygen is greater than that of nitrogen. Test runs were limited to a maximum of 300 F because the reaction of pure oxygen at higher temperatures was sufficient to produce errors in the data. Average deviations from the mean for the eight fuels were less than ±6%.



SOLUBILITY OF CARBON DIOXIDE, decreases as temperature increases in the range from about 100 to 400 F. Above 400 F, it increases with temperature. At low temperatures, solubility obeys Henry's Law at low partial pressure but shows some deviation at high pressures. As the temperature increases, the gas shows nearly ideal behavior for the entire pressure range. Fuels investigated deviate by less than ±6% from the average solubility shown.

Flight Experience

Based on paper by

M. G. Beard

American Airlines, Inc.

POWERPLANTS of the new 707 have given almost no trouble, but there have been more difficulties with wiring and electronic equipment than anticipated. This is in direct contrast with DC-6 and DC-7 experience.

A review of 57 schedules shows planned "off" to "on" time missed by some considerable margins. 66% took more than planned time; 10% took 10 min less. Whether higher than anticipated headwinds or required changes in altitude were responsible for the excess time in each case has yet to be determined. Nearly all overtime schedules showed one or more changes in altitude from flight plan. Schedules showing less than flight plan time had better winds than forecast. Where there was greatest overtime, long-range cruise was used instead of maximum cruise thrust.

Use of water on take-off

The JT3C-6 engine requires water injection at all temperatures down to −5.5 C to develop 13,000 lb of thrust. Water tank capacity is 700 gal, or enough for 2.2 min from start to take-off when water is injected into both inlet and diffuser. Below 4.5 C water is injected into the diffuser only. All the water put in the tank is used on the take-off. Under certain conditions less than full use of water is permitted and then more payload or fuel can be carried.

Thus far there have been few instances where the airplane has been slowed down because of clear air turbulence. The flexible swept wings absorb most of the turbulence so that very little motion is felt in the cabin. Cruise is usually performed on autopilot and frequently some of the climb and the first part of descent. During instrument weather, traffic control dictates the altitudes over which check points descent rates are usually determined. Cabin descent rates usually can be kept at 300 fpm or less.

Advent of third pilot

Proving runs showed the crew to be much busier with computations and communications with control centers than ever before. Often the report of time over one check point cannot be completed before the next check point is passed. Moreover, a large percentage of flights are required to change planned altitude because of traffic ahead on the originally assigned altitude. All this adds up to much more communication and flight planning enroute than anticipated and frequently both pilots are busy with such work while the autopilot does the flying.

Obviously, protection of traffic by watching from windows is lacking when both pilots have their eyes on maps and route planning forms. Therefore, we planned to have a third pilot as soon as cockpit accommodations could be arranged. He is not yet functioning on all 707's. He is designated the Second Officer and his duties are communications and navigation. When one of the pilots leaves his cockpit seat, the second officer will occupy it immediately and will act as backup whenever it is necessary for the Flight Engineer to leave his station.

Ground time performance

Ground time from ramp to take-off and from landing to ramp is longer than for piston plane operation, which has been 12 min, an average time taking into account taxiing, engine runup, and average traffic and weather hold before take-off. An analysis of 52 nonstop schedules flown in March 1959 showed ground time averaging 19.7 min, with westbound flights taking 21.1 min and eastbound 17.7 min. The difference is probably due to the

with the 707

longer taxiing distance at Idlewild to get to take-off and to more delays due to weather and traffic in the New York area than at Los Angeles.

The average age of pilots checking out on the 707 is slightly above 50 years, but age seems to have no bearing on checking out time. Some of the older pilots have been among those in the lower time bracket.

Pilot training problems

Use of the flight director system in instrument approaches requires the most time and gives the pilots the most difficulty in training. At start of training not all of the flight aid was in operation and training was running about 20 hr per man. With full aid installed, the pilots received 4–5 days or 12–20 hr on them, and flight time needed to qualify fell to about 15 hr. With more experience in instruction on items giving difficulty, flight time should drop to about 12 hr.

Flight training is always done with the yaw damper off to give the pilot a better feel of the 707's characteristics. In scheduled operation the damper is used most of the time while flying manually for steadiness and passenger comfort.

Swept wing jet transports, which attain higher ground speeds on take-off and higher landing speeds than the Constellation and DC-7's, must be actually flown, especially laterally, while the airplane is at the higher ground speeds. It is particularly necessary in cross-wind operation because the geometry of the engine pods and landing gear with respect to ground and lateral tilt makes it possible to contact the outer pod on the ground with 7–8 deg lateral roll.

Damage from slush

When a snowstorm ending in rain hit New York in March, several piston-engined transports sustained small damage while operating in the 1–3-in. slush on LaGuardia and Idlewild runways. The Boeing 707 suffered very minor but unusual damage. During take-off, the impact of slush thrown from the main gears rolled skin over rivet lines whenever it got under an edge, such as the edges of inspection covers and the edge of the cargo door frame, and damaged flaps and other metal structure.

The high speed on the runway imparts greater force to slush and water thrown by the gear than ever before experienced and apparently great care will have to be exercised when operating in snow, slush, and deep water pool conditions. This situation is under study and should yield information on the amount of slush and water that can be negotiated on take-off.

Charts for flight planning

Rapid, accurate flight planning depends upon putting airplane performance and speed/power/consumption data into curves and charts so that the crew can analyze the flight at several altitudes within a reasonable flight planning time before departure. Engineering performance curves are totally inadequate. The information necessary to organize these charts must be accurate and represent the closest possible fleet average. Any change in the drag characteristics or the consumption of the engines necessitates a complete revision of the charts. If an airline allows these aerodynamically clean jets to become aerodynamically dirty, the charts will have to be revised frequently. And vice versa, it will be easy for the operations department to spot discrepancies in individual transports by checking their cruising performance against the charts.

Passenger acceptance of the 707 has exceeded our fondest hopes and we are satisfied that this transport will have a long and useful history in airline operation.

To Order Paper No. 62T . . .
. . . on which this article is based, turn to page 6.

How to anchor sprayed metals

Surface preparation and cleanliness are of supreme importance. Improved techniques are bringing greater bond strengths, denser coatings, and reductions in cost.

Based on paper by

Walter B. Meyer

St. Louis Metallizing Co.

RECENTLY developed . . .

. . . are procedures for impregnating the porous structures of sprayed deposits with various plastic formulations. These formulations may be:

- **Polyvinyl chlorides**
- **Epoxies.**
- **Catalyzed phenols.**
- **Phenol-epons.**
- **Heat-cured phenols.**

These materials are introduced into the pores of the sprayed metal, displacing the air and resulting in an impervious barrier.

When these new procedures are used with sprayed metals cathodic to iron or steel (such as stainless steels, nickel, or monel metal) they must be carefully tested prior to use. Sprayed metal thicknesses, impregnating procedures, and the choice of the right plastic material are all critical. . . . But, application of plastic materials to sprayed metals anodic to steel (such as zinc and aluminum) is in nowise so critical, and is quite easily accomplished.

SPRAYED metal coatings are, with but few exceptions, attached to the base material by mechanical means. Surface preparation and cleanliness are of supreme importance.

The work piece is first turned down to provide space for the sprayed metal inlay. The undercut will depend on the size of the piece, the amount of wear anticipated before again rebuilding, and the type of metal to be deposited.

To prepare an undercut surface for reception of sprayed metals, any one of several methods may be used:

- Rough threading — one of the earliest methods.
- Groove and knurl method — a later more positive process.
- Electric bonding.

Rough threading (Fig. 1) is accomplished by threading the surface in such a manner as to fracture the sides of the threads. Thus, myriads of fissures and "dovetails" are created, into which the molten particles of metals are driven. As these particles "freeze," they are keyed tightly to the base metal in a pureply mechanical bond.

This process, now almost obsolete, creates many points of stress concentration at the thread roots. Moreover, it depends greatly on the operator's personal conception of a proper degree of roughness . . . as well as on the ability of any given metal to roughen suitably.

The "groove and knurl" method is more positive in its results. The shaft is mounted on a lathe. Then, after turning undersize, it is grooved as shown in Fig. 2. The tool bit is of standard ⅛-in. cut-off tool blade, ground on the side to cut the type of groove shown. (The radius on the corners of the tools should not be over 0.020 in.)

The grooves may be made by:

- Using the lathe lead screw and cutting a continuous thread . . . or
- Cutting a number of separate grooves.

Where possible, a dove-tail is desirable at the

shoulder at both ends of the section to be metallized.

Second step in the groove and knurl method is to apply a rotary roughening tool — which is mounted on the tool post with the toothed wheel square with the work. The tool is run back and forth over the shaft to roughen the surface on top of the ridges and to spread the ridges. Thus, the dove-tailed grooves are formed. The ridges are spread so that their tops are about the same width as the spaces between.

This procedure eliminates the sharp points which bring stress concentration . . . and results in a surface which can be visually inspected. But it can be used only on machinable metals.

Electric bonding is achieved with a special electric bonding machine (Fig. 3). Electrical resistance heating of special nickel electrode material, as it is applied to the base, causes the electrode metal to be exploded simultaneously into a foam and firmly fused to the base metal. The metal foam has a structure comparable to frozen soap suds, with many irregularly-shaped cavities over its entire surface.

Most recent is use of a special molybdenum wire, which is sprayed as a bonding coat directly on to the work. . . . by deposition via a conventional metal spraying unit. A thin layer of molybdenum is deposited on a chemically clean metallic surface, preferably one which has been roughened by an abrasive blast

The final result of the electric bonding method is an extremely rough and porous surface . . . an ideal bond for subsequent coatings of sprayed metal.

For extreme bond strength — regardless of the preparation method used — it is desirable to thread, or otherwise corrugate, the surface immediately prior to application of molybdenum.

Sand blasting usually prepares large flat areas for reception of corrosion-resistant coating. Very sharp, angular abrasives are projected through a pressure-type blasting machine.

Until recently, sprayed metal coating applied to large flat areas for resistance to corrosion was limited to those metals anodic to iron and steel.

To Order Paper No. 40R . . .
. . . on which this article is based, turn to page 6.

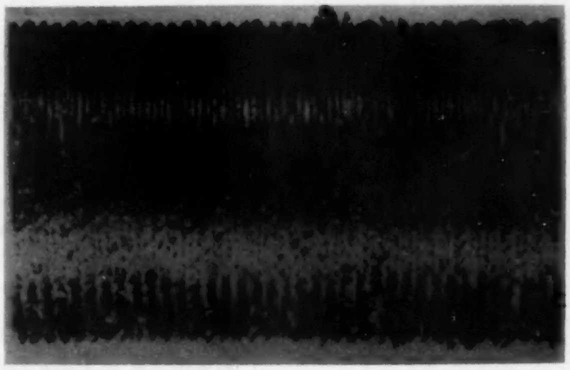


Fig. 1 — Rough threading creates myriads of fissures into which molten particles of metal are driven. This method of anchoring sprayed metals is almost obsolete.

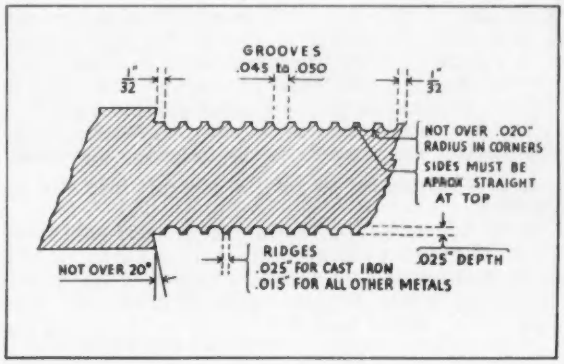


Fig. 2 — "Groove and knurl" method of anchoring sprayed metals is accomplished by mounting the shaft on a lathe. Then, after turning undersize, it is grooved as shown here.

Fig. 3 — Electric bonding method is achieved with a special bonding machine.

Which Starter Will *You* Use?

• There are hundreds of starter system combinations for jet engine aircraft. Here are some basic components and their characteristics.

THE JET AIRCRAFT designer and operator can now pick from several engine starting systems and will have more to choose from in the future. The choice for a particular aircraft will continue to depend on aircraft characteristics and intended use.

The decision, in any case, can be speeded up by first finding the answers to the following questions:

1. Is it important to get the aircraft into the air quickly?

If it is, one of the high-energy, self-contained starting systems will probably save 2–3 min, on the average, over ground supported systems for multi-engine aircraft. Single-engine aircraft can save 1–1⅓ min. About half this saving is due to the use of a high-energy system instead of a low- or moderate-energy system.

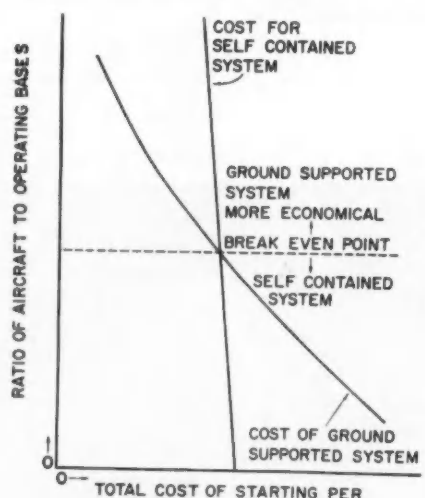


Fig. 1 — First choice to be made in starting jet engines is whether the system should be self-contained or not. A cost plot similar to this chart is one of the three answers that will direct the decision.

2. Will the aircraft be operated periodically from remote and widely scattered bases or airports?

If so, self-contained starting is almost mandatory, while many bases are today equipped with ground carts, they may not be suitable for a particular installation.

3. What will be the ratio of aircraft to operating bases?

Fig. 1 shows the type of calculation that must be made in order to decide "self-contained" or "ground-supported." This plot is especially desirable for fleets that are expected to change in mode of operation over a period of time. It will show up the economics for later additions to the fleet or to the system route plan. On the plot, the cost of self-contained systems will be substantially fixed regardless of the ratio of aircraft to bases. Variations result from slight economies due to lowered spares support, and reduced unit training costs.

After the three questions have been answered and a choice between self-contained or ground-supported systems made, there are a variety of starter mechanisms and power supplies available. Combinations of these units would have to be investigated to answer the third question properly.

There are four basic types of mechanisms that can be used to turn over the jet engine. They are: direct impingement, pneumatic, hydraulic, and electric.

Direct Impingement — This is the simplest form of starter. Here, gas is blown at the jet engine turbine wheel through a special set of starting nozzles, thus bringing the engine up to speed. At present, this method is impractical for large engines because the starting nozzle hardware cannot be properly designed without interfering with the main flow of air through the engine. In fact, two to four times as much gas is needed compared to a geared gas turbine starter. Also, most engine manufacturers object to the passage of possibly incompatible gases through their engines.

Pneumatic Starter — The pneumatic starter generally consists of an air inlet manifold, turbine, reduction gearing, overrunning clutch or disc clutch,

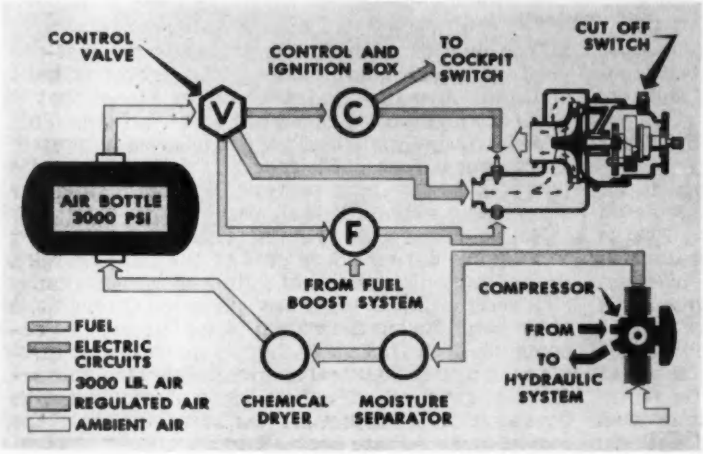


Fig. 2 — Most widely used self-contained starting system today is the fuel-air combustion starter. High-pressure air is used to support combustion and pressurize the fuel system. A small compressor recharges the air bottle during flight.

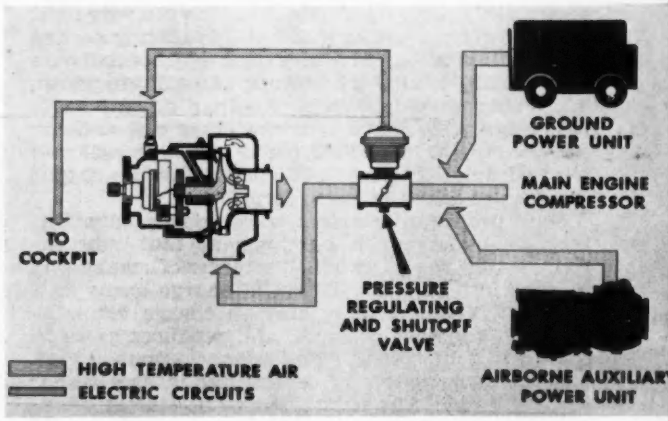


Fig. 3 — This simple lightweight pneumatic starter can be driven by an auxiliary power unit or a ground cart. If the APU is already aboard the aircraft, the weight chargeable to the starting system is low.

and an engine decoupling mechanism. The power supply may be from the ground cart, an airborne system, or another engine of the aircraft. The simple pneumatic starter seldom operates with gases over 500 F or 50 psi.

There are two main variations of the pneumatic starter in which part of the starting power is generated at the starter itself. These are the *combustor supported pneumatic starter* and the *fuel-air combustion starter*. These combinations are reviewed in following sections on power supplies.

Hydraulic Starters — A hydraulic pump-motor unit is directly connected to the engine gearing. During the starting cycle, the unit acts as a hydraulic motor being supplied with a flow of hydraulic fluid from an outside source. After engine starting, the unit can be made to function as a pump to provide hydraulic fluid for the aircraft.

Electric Starters — Although extremely reliable, this method can hardly be considered for large jet engines with self-contained systems. However, it could be used to start one or more engines of a multiengine plane using the small series of engines now being developed. The other engines could then be started by compressor bled air from the running engines. The starter would then act as a generator to provide d-c power for the aircraft. The use of a-c starting units is quite impractical at the present time.

Power sources for starting

Considering only self-contained systems, the most widely used starter is the **fuel-air combustion starter.** The "outside" power is a supply of compressed air, which is made available at 200–300 psi. This compressed air is used both to support combustion and to pressurize a fuel system. Combustion takes place in a chamber in the starter. This high-energy gas then drives a turbine, and starting is similar to a simple pneumatic system. The main difference is the high energy of the combustion gases, making fast starts possible. The starter components are similar to the simple pneumatic system except for increased ruggedness and higher-tem-

Material for this article was drawn from the following papers:

"A Study of Self-Contained Starting Systems for Turbojet and Turboprop Engines"
by Henry R. Schmider and **John H. Ferguson, Jr.**
Utica Division, Bendix Aviation Corp. (Paper No. 48T)

"Positive-Displacement Motors for APU Power Requirements"
by Fred Klemach
Aero-Hydraulics Division, Vickers Inc. (Paper No. 53R)

"Modern Gas Turbine Auxiliary Powerplant Characteristics and Applications"
by Paul G. Stein
AiResearch Mfg. Co. of Arizona (Paper No. 53S)

To order any of the above papers . . .
. . on which this article is based, turn to page 6.

perature materials. A relatively flat torque output curve results from the high gas velocities at the turbine wheel, 4000–5000 fps. A schematic of the system is shown in Fig. 2.

The 3000-psi air bottle is recharged during flight by a small compressor.

Combustor-supported pneumatic starting is an in between system. A 3000-psi air bottle is regulated to 50 psi and passed through a combustor. Fuel is added and burned to raise the gas temperature to 700–1000 F. This moderately high energy gas then drives the pneumatic starter. Adding water will help cool the gases and add to the mass flow. Since the torque characteristics of turbines are mainly dependent on mass flow, the result is a saving in stored air weight and the size of the air bottle.

Airborne auxiliary power units (APU) can be used for starting, along with their many other functions. In such a case they would use the low-pressure pneumatic starter. (See Fig. 3.) This is a very light weight form of starting if the APU is already needed for such things as air-conditioning (especially on the ground), auxiliary hydraulic and electric power, and cabin pressurization. Another advantage is that it is a truly continuous starter, as well as being self-contained. The APU could also be considered for hydraulic or electric starting, since its output can also be taken in these forms.

Solid propellant starters or cartridges have just recently undergone a development that substantially solved the early 1950 problems of smoky and highly erosive gases. The solid charge burns at a constant rate depending only on charge temperature and chamber pressure, and produces gases in the vicinity of 2000 F. The energy output is high and the torque curve of the turbine is, as a result, relatively flat. The cartridge can be starter or remotely mounted. The overall system is lighter than fuel-air combustion starters. Disadvantages are the need for a propellant that is less affected by temperature, the high cost per start (around $50), and the need to carry as many cartridges as anticipated starts (about 12 lb apiece) or have them stocked at airports. One recent development used in conjunction with the cartridge is the hot-gas **positive-displacement motor.** This motor is built along the lines of a hydraulic motor except that it uses cartridge gases instead of hydraulic fluid. This allows extremely efficient use of the gases generated. The motor can be built integrally with a hydraulic pump to supply high-pressure hydraulic fluid for starting. A schematic is shown in Fig. 4.

Hot gases enter the cylinders through a stationary valve plate during all or part of the power stroke, depending on the choice of a full- or partial-admission design. Spent gases are exhausted through the valve plate during the return piston stroke. To accommodate the hot gases, high-wear-resistant metals with nearly identical thermal expansion characteristics are used. The housing is pressurized with hydraulic fluid to prevent gas leaks, lubricate the motor, and dissipate heat. Three methods of regulation can be used:

- Constant gas pressure regulation valve in the motor inlet line.
- Hydraulic relief valve in the hydraulic load circuit.
- A pressure-compensated pump, with pump displacement varying in response to small changes in outlet pressure.

The third system has the advantage of not dissipating hydraulic power through a relief valve. Overheating of the hydraulic fluid is also prevented. A definite saving is gas generator and propellant weight can be realized if a propellant is used that decreases its burning rate in response to a decrease in gas pressure. If the motor is to be used for a highly varying load over longer-than-starting times, liquid propellants will show a weight saving because of their controllable burning rate.

Liquid monopropellant starters are high-energy devices that use the decomposition of chemicals such as hydrogen peroxide, iso-propyl nitrate, and hydrazene to drive a turbine starter. They could be considered in cases where these fuels are already on board. However, these chemicals are difficult to handle, and at present there are no operational installations of such equipment in this country.

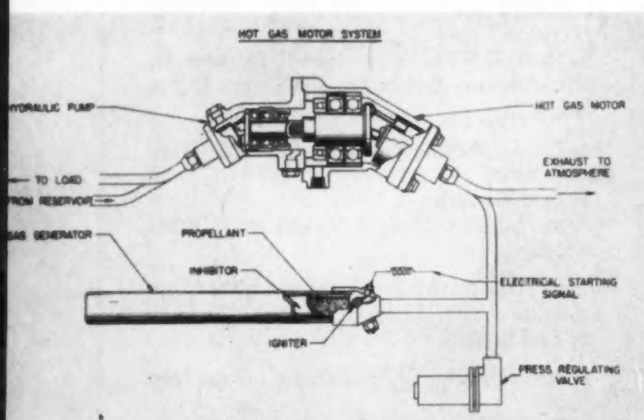


Fig. 4 — Positive-displacement motor makes efficient use of cartridge high-energy gas supply. The motor can be made to drive an integral hydraulic pump, which uses the same bearings and housing. This unit can also be used for general short-duration, high-energy, auxiliary power.

Future starting possibilities

Three possible future systems are:

- *Self-Breathing Starting Systems* — Here, a miniature jet engine would be used as a starter. Russia has used this system for some time; however, the system shows no particular advantage over systems used in this country.
- *Oxygen Combustors* — Air bottles could be charged with oxygen, thus eliminating 80% inert nitrogen now carried. Main problem with this system would be the high temperatures resulting from pure oxygen burning.
- *LOX-Water-Fuel Combustors* — These materials are already carried on aircraft and could be combined to form a high-energy gas supply for the starter turbine. The major deterrent is the high rate at which liquid oxygen would have to be converted to gas. This system may become more practical with any widespread usage of reigniting engines after flameout by filling the combustion chamber with oxygen.

Muffler Location Is Important

Based on paper by

T. A. Danner

Arvin Industries, Inc.

THERE are several reasons why the location of the muffler with respect to other exhaust system components is important if the most efficient use of available muffler volume is to be gained. Among these reasons are the acoustical tuning of the muffler and the tuning of the pipes themselves.

Forward Positioning

When the muffler is positioned near the forward part of the car, the conventional location, the natural frequency of the exhaust pipe is approximately twice that of the tail pipe. The length of the tail pipe may not be exactly twice that of the exhaust pipe, but since the velocity of sound varies with temperature, the "acoustical" length of the exhaust pipe can be said to produce a frequency ratio twice that of the tail pipe. When this condition exists, muffler design can be such as to use the frequency relationship of the pipes.

If a muffler of sufficient volume is possible, two low frequency resonators can be used, one tuned to the fundamental frequency of the tail pipe, the other to the fundamental frequency of the exhaust pipe. Then, as the firing frequency is increased to the natural frequency of the tail pipe, this pipe will be excited at its natural frequency and the exhaust pipe will be excited at half its natural frequency. Since one of the resonators is tuned to this frequency, sufficient attenuation of the resonator will reduce the excitation of the tail pipe to suppress this note. The excitation of the exhaust pipe at half its natural frequency will not add to the excitation of the tail pipe to any extent greater than can be suppressed by the resonator. When the firing frequency is increased to the natural frequency of the exhaust pipe, suppression is adequate because the second resonator is tuned to the natural frequency of the exhaust pipe and the first overtone of the tail pipe.

From the foregoing it can be seen that the resonator tuning couples with the pipe tuning to suppress all of the natural frequencies of the pipes and their overtones with resonator volumes that are economically feasible. This widely used front location allows design of mufflers with minimum volume for acceptable silencing.

Center Positioning

If the muffler is located in the center of the exhaust system, or where the acoustical lengths of the exhaust pipe and tail pipe are approximately equal, conditions are altered. As the firing frequency equals the natural frequency of the exhaust pipe it also equals that of the tail pipe. This is also true for all overtones and harmonics of both pipes and it requires that the muffler for this position have a larger volume and more involved design than one used in the forward position. Even with two resonators tuned to the natural frequency of both pipes, note suppression requires larger volumes in the muffler and very careful tuning. Any other combination of tuning of the resonators in the muffler results in less efficient use of the volume.

Centrally located mufflers would be far less economical and more difficult to design than those for front location.

Extreme Rear Positioning

If the muffler is located at the extreme rear, the short stub tail pipe has no bearing on the system periods since its frequency is completely out of the driving range. There is only one frequency to consider — the exhaust pipe length, and if the vehicle is long enough this frequency can be lower than the idle firing frequency of the engine. In this system overtones are the only consideration and they can be suppressed adequately with various types of resonator tuning. In some instances only one low frequency resonator in the muffler is necessary. Some overrun noises have been experienced that require specific design characteristics in the muffler, but from a note or period standpoint the rear location may be worth consideration in exhaust system design.

To Order Paper No. 38T . . .
. . . on which this article is based, turn to page 6.

Air Force program evaluates

the machining characteristics of

Vasco Jet 1000 Die Steel

Based on paper by

P. R. Arzt, J. V. Gould, and J. Maranchik, Jr.

Metcut Research Associates, Inc.

AN AIR FORCE research program is providing valuable data on machining the martensitic low-alloy steels, hot-work die steels, and martensitic stainless steels in the high-hardness ranges.

This article discusses results, to date, obtained with Vasco Jet 1000 hot-work die steel, quenched and tempered to 50–55 Rockwell C.

Turning tests

Turning proved to be the least difficult of the various types of machining operations being studied for the ultra-high-strength thermal-resistant alloys. It was possible to obtain reasonable tool life in turning without resorting to unusual types of tools, tool geometries, or techniques. Good tool life results can be obtained by adhering to the following general recommendations:

1. Use a rigid machine, and strong, solid tools and fixtures.
2. Use the proper type of carbide. For a given type of carbide, select the hardest grade that will perform without chipping.
3. Use cutting speeds, feeds, and tool geometries selected from turning data obtained under controlled cutting conditions.

THIS ARTICLE on Vasco Jet 1000, quenched and tempered to 50-55 Rockwell C, is the result of an Air Force program set up to evaluate the machining characteristics of the more commonly used high-strength thermal-resistant materials. The work is being performed by Metcut Research Associates, Inc. under contract to Wright Aeronautical Division of the Curtiss-Wright Corp.

AISI 4340, another material tested under this program, was discussed in May's SAE Journal. AM-350 and A-286 will be discussed, respectively, in the July and August issues of SAE Journal.

Tool life results for turning Vasco Jet 1000, quenched and tempered to 52 R_c, are presented in Figs. 1 and 2.

Milling tests

The problem which stands out above all others is the milling of the high-strength thermal-resistant alloys in airframe and missile components. The problem was brought about by the change from aluminum to high-strength-steel airframe components. Listed below are the important types of milling operations and typical cuts being made for each type of milling operation.

Operation	Dimensions of Cut
Face milling	0.060 in. to 0.250 in. depth
	1 in. to 5 in. width
End milling	Pockets —
	4 in. × 4 in. to 8 in. × 8 in. area
	¼ in. to 3 in. depth
	Pockets in thin sheet —
	8 in. × 10 in. area
	0.025 in. to 0.050 in. depth
	Milling side of rib —
	0.020 in. to 0.060 in. depth
	2 in. to 3 in. height of rib
	Profiling —
	0.060 in. to 0.300 in. depth
	½ in. to 2 in. width
Side milling	Spars —
	½ in. to 2 in. width
	⅛ in. to ½ in. depth
	up to 25 ft length
Slot milling	Hinges —
	3/16 in. to ½ in. width
	½ in. to 1 in. depth
	½ in. to 1 in. length
	Clevises —
	¼ in. to 1 in. width
	1 in. to 2 in. depth
	1 in. to 3 in. length
	Wing spar —
	1 in. to 2 in. width
	1 in. to 1½ in. depth
	Up to 15 ft length

Emphasis will be given here to information and data obtained in milling Vasco Jet 1000 in the high-hardness ranges.

Cutter geometry studies made in face milling Vasco Jet 1000, quenched and tempered to 50 R_c, indicated that an axial rake of 0 deg and a radial

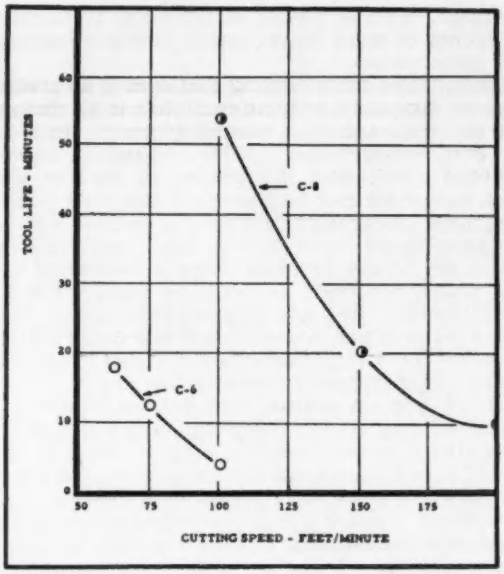


Fig. 1 — Turning Vasco Jet 1000 quenched and tempered to 514 Bhn (52 Rockwell C); effect of carbide. Tool: carbide (see graph); side rake: 5 deg neg.; back rake: 5 deg neg.; nose radius: 0.032 in.; side cutting edge angle: 15 deg; end cutting edge angle: 15 deg; relief: 5 deg. Mechanical chip breaker. Feed: 0.009 in. per rev.; depth: 0.100 in.; cutting fluid: none; wearland: 0.015 in.

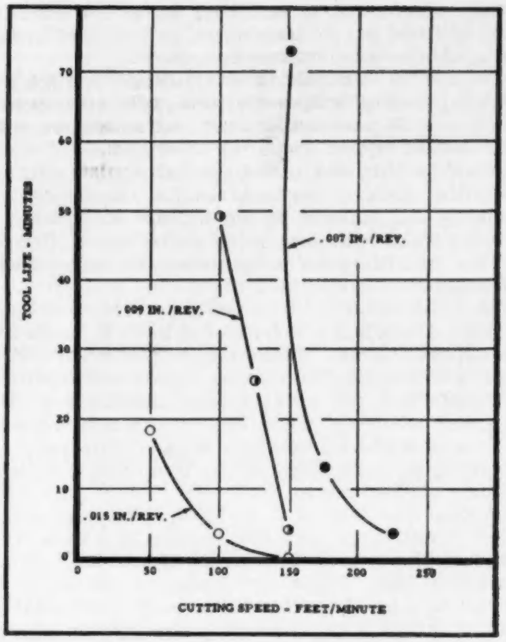


Fig. 2 — Turning Vasco Jet 1000 quenched and tempered to 514 Bhn (52 Rockwell C); effect of feed rate. Tool: C-8 carbide; side rake: 5 deg neg.; back rake: 5 deg neg.; nose radius: 0.032 in.; side cutting edge angle: 15 deg; end cutting edge angle: 15 deg; relief: 5 deg. Mechanical chip breaker. Feed: see graph; depth: 0.100 in.; cutting fluid: none; wearland: 0.015 in.

rake of – 15 deg, with a 45 deg corner angle produced the best tool life. The carbide evaluation proved interesting in that a C-2, general purpose, nonferrous grade of carbide produced considerably better tool life than a C-6, general purpose, steel cutting grade.

The tool life curve (Fig. 3) obtained when face milling 50 R_c Vasco Jet 1000 shows that with a 5-tooth cutter, a C-2 grade of carbide, and a feed of 0.005 in. per tooth, 400 in. of material can be milled at a cutting speed of 125 fpm. For the same cutting conditions, tool life was only 75 in. when face milling with a C-6 grade of carbide.

Tests made to study the effect of feed indicated that a feed of 0.005 in. per tooth was best when face milling the Vasco Jet 1000 alloy. At higher feed rates, from 0.010 to 0.015 in. per tooth, localized rather than uniform wear takes place on the cutter teeth.

For side milling Vasco Jet 1000, quenched and tempered to 52 R_c, down milling with a C-2 grade of carbide was found to give best results (Fig. 4). At a cutting speed of 145 fpm and 0.0075 in. per tooth feed, a tool life of 90 in. length of cut was obtained with a single-tooth cutter with 0 deg axial rake and – 15 deg radial rake. Almost immediate cutter breakdown was encountered when attempting up milling at the same cutting conditions.

Fig. 5 shows a tool life curve for a 6-tooth cutter. Maximum tool life was 390 in. work travel to obtain a 0.012 in. uniform wearland on all teeth.

The end milling tests consisted of milling ¼ in. deep slots using ¾ in. diameter high-speed end mills and 1¼ in. diameter carbide end mills. Tool life is

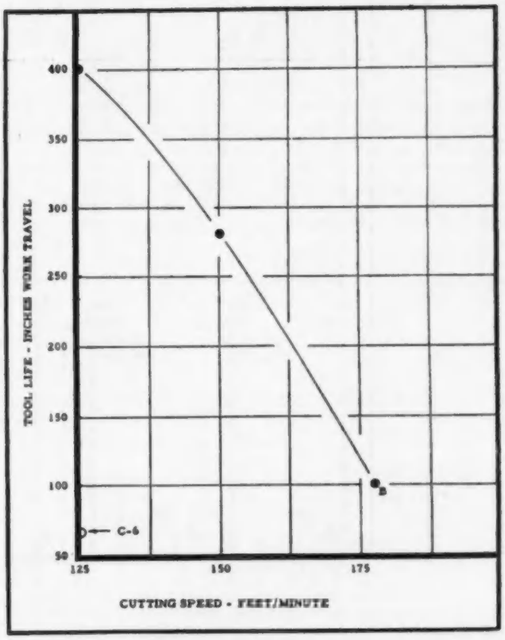


Fig. 3 — Face milling Vasco Jet 1000 quenched and tempered to 50 Rockwell C; multiple tooth cutter. Tool: 5 in. diameter OK face mill — 5 teeth with C-2 carbide. Axial rake: 0 deg; radial rake: 15 deg neg.; corner angle: 45 deg; true rake: 10 deg neg.; angle of inclination: 10 deg; end cutting edge angle: 5 deg; clearance: 8 deg; feed per tooth: 0.005 in.; depth: 0.100 in.; width: 2 in.; cutting fluid: none; wearland: 0.015 in. End of test determined by localized breakdown.

given in inches of work travel for a tool life end point of 0.016 in. uniform wear, or localized breakdown, whichever occurred first.

Tool life for end milling Vasco Jet 1000, quenched and tempered to 52 R_c, with high-speed steel cutters was extremely poor. All subsequent tests were made with carbide tipped tools. As shown in Fig. 6, a C-2 grade of carbide and a mist coolant applied through the cutter yielded the best results. Optimum tool geometry for carbide-tipped cutters was found to be 0 deg axial rake and 0 deg radial rake. Chatter and low tool life were encountered for both positive and negative rake angles.

Fig. 7 shows a tool life curve for end milling Vasco Jet 1000, quenched and tempered to 52 R_c, with carbide-tipped cutters. Maximum tool life was 105 in. work travel at 60 fpm cutting speed and 0.0015 in. per tooth feed. At lower speeds, chatter and tooth chippage occurred. Tool life decreased slowly with increasing speed dropping to 30 in. at 210 fpm.

Machining tests using a 6 in. diameter, 1 in. wide slotting cutter were made on Vasco Jet 1000, quenched and tempered to 52 R_c. The tests consisted of milling a slot 0.250 in. deep by 1 in. wide in the workpiece on a Cincinnati No. 6 High Power Horizontal Mill. To obtain maximum rigidity of the set-up, a 2 in. diameter arbor was used and the slotting cutter kept as close to the spindle nose as possible. Overhang of the overarm was kept at a minimum. Tool life when slotting was recorded as the inches of work travel before cutter breakdown took place.

The initial testing consisted of a carbide evaluation and rake angle evaluation to determine the best tool material and tool geometry for slotting the hardened alloys. The carbide evaluation showed that the nonferrous C-2 grades of carbide were much better for slot milling than the steel cutting C-6 grades of carbide. With a C-2 carbide tool life was about four times higher than that obtained with a C-6 grade carbide. The C-2 carbide wore very uniformly along the cutting edge, while the C-6 grade fractured and chipped very badly. Tests with a C-3 grade of carbide provided a tool life about the same as that obtained with a C-2 grade, but severe chipping was evident on the teeth.

The rake angle evaluation indicated that a rake combination of bi-negative 5 deg axial rake and −10 deg radial rake produced the highest tool life. The face of the carbide tooth was ground to produce the bi-negative 5 deg axial rake on both corners of the tip. When looking at the carbide tip in a radial plane, the cutting edge face shows a wedge shape because of the −5 deg axial rake ground on both corners. Both corners were ground with a 0.030 in. wide 45 deg corner angle.

Down, or climb, milling shows a 3 to 1 improvement in tool life over up, or conventional, milling

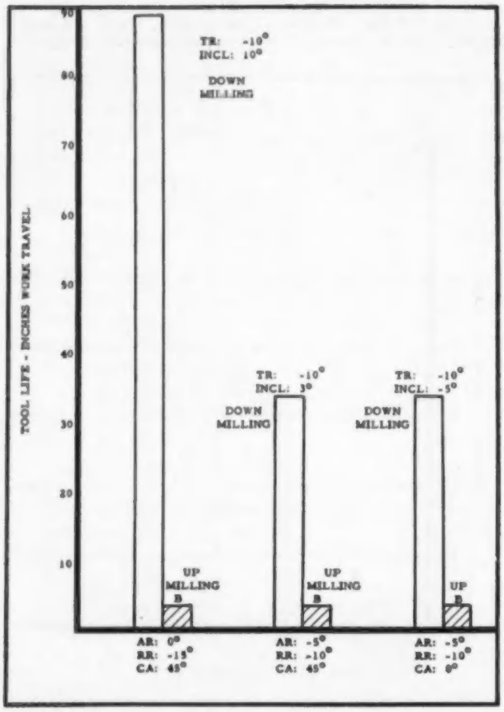


Fig. 4 — Side milling Vasco Jet 1000 quenched and tempered to 52 Rockwell C; effect of tool geometry — single tooth cutter. Tool: 7 in. diameter face mill with C-2 carbide; clearance: 8 deg; end cutting edge angle: 5 deg; cutting speed: 145 fpm; feed per tooth: 0.0075 in.; depth: 0.100 in.; width: 1.75 in.; cutting fluid: none; wearland: 0.012 in. End of test determined by localized breakdown.

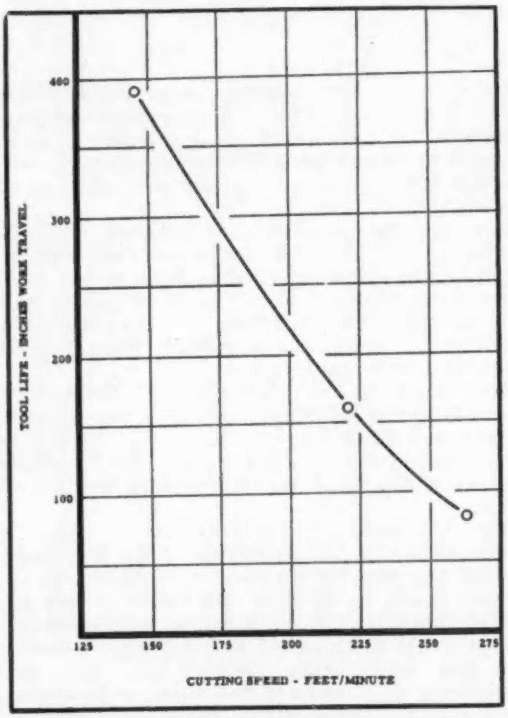


Fig. 5 — Side milling Vasco Jet 1000 quenched and tempered to 52 Rockwell C; multiple tooth cutter. Tool: 7 in. diameter face mill — 6 teeth with C-2 carbide; axial rake: 0 deg; radial rake: 15 deg neg.; corner angle: 45 deg; true rake: 10 deg neg.; angle of inclination: 10 deg; end cutting edge angle: 5 deg; clearance: 8 deg; feed per tooth: 0.0075 in.; depth: 0.100 in.; width: 1.75 in.; cutting fluid: none; wearland: 0.012 in. End of test determined by localized breakdown.

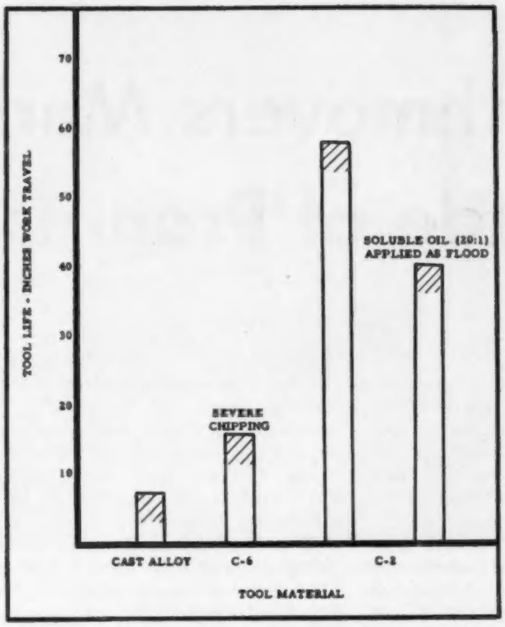


Fig. 6 — End milling Vasco Jet 1000 quenched and tempered to 52 Rockwell C; carbide cutter — effect of carbide grade. Tool: 1¼ in. diameter 4-tooth end mill. Axial rake: 5 deg neg.; radial rake: 0 deg; true rake: 0 deg; end cutting edge angle: 3 deg; corner angle: 45 deg, 0.030 in. wide; peripheral clearance: 15 deg; end clearance: 5 deg; cutting speed: 50 fpm; feed per tooth: 0.0015 in.; depth: 0.250 in.; width: 1.250 in.; cutting fluid: chemical emulsion (40:1) applied as mist through cutter; wearland: 0.015 in.

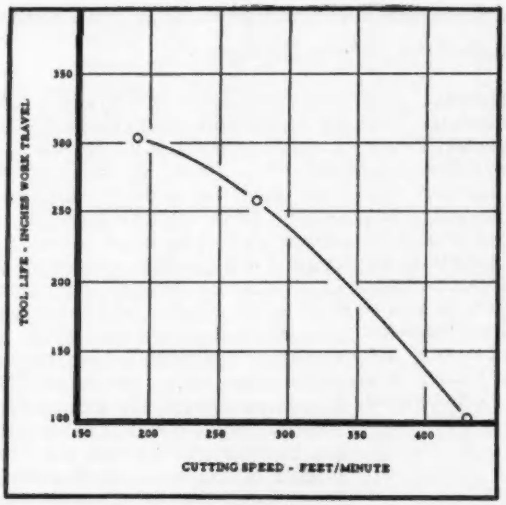


Fig. 8 — Slotting Vasco Jet 1000 quenched and tempered to 52 Rockwell C; multiple tooth cutter — down milling. Tool: 6 in. diameter tooth cutter with brazed-on C-2 carbide; axial rake: 5 deg; true rake: 10 deg neg.; radial rake: 10 deg neg.; angle of inclination: 10 deg; corner angle: 45 deg, 0.030 in. wide; end cutting edge angle: 1 deg; peripheral clearance: 8 deg; feed per tooth: 0.005 in.; depth: 0.250 in.; width: 1 in.; cutting fluid: none; wearland: 0.012 in.

in the slotting cuts. With conventional milling considerable vibration was noted in the milling setup even when light feed rates of 0.003 to 0.005 in. per tooth were used.

The tool life curve when slot milling 52 R_c Vasco Jet 1000 is shown in Fig. 8. The tool life tests were made using the 6 in. diameter brazed tooth cutter with brazed-on C-2 grade carbide tips. Maximum tool life for a 0.012 in. wearland tool life end point was 300 in. of work travel at a cutting speed of 190 fpm and a feed of 0.005 in. per rev. Good tool life was obtained at cutting speeds from 190 to 300 fpm.

The drilling tests performed on the ultra-strength alloys consisted of drilling ¼ in. diameter by ½ in. deep through holes. Drill life end point was an arbitrary 0.015 in. wearland on the drill margin or complete breakdown, whichever occurred first.

Drill life data for 52 R_c Vasco Jet 1000 are presented in Fig. 9.

To Order Paper No. 43R . . .
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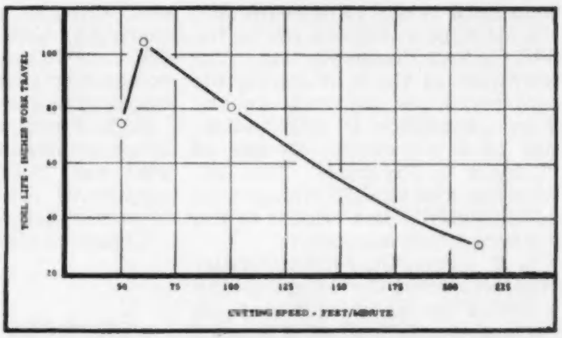


Fig. 7 — End milling Vasco Jet 1000 quenched and tempered to 52 Rockwell C. Tool: 1¼ in. 4-tooth end mill with C-2 carbide; axial rake: 0 deg; true rake: 0 deg; radial rake: 0 deg; end cutting edge angle: 3 deg; corner angle: 45 deg, 0.030 in. wide; peripheral clearance: 15 deg; end clearance: 5 deg; feed per tooth: 0.0015 in.; depth: 0.250 in.; width: 1.250 in.; cutting fluid: soluble oil (20:1) applied as mist through cutter; wearland: 0.015 in.

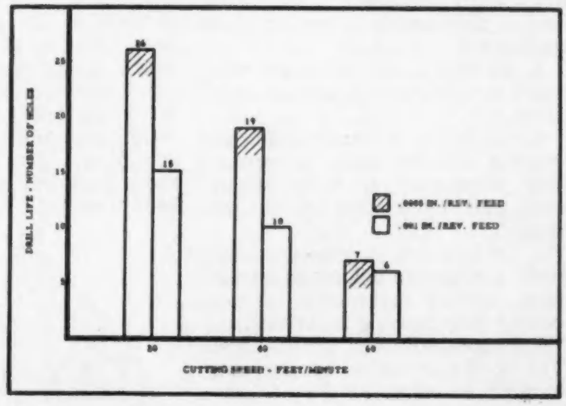


Fig. 9 — Drilling Vasco Jet 1000 quenched and tempered to 52 Rockwell C; effect of cutting speed and feed. Drill: T-15 HSS; diameter: 0.250 in.; length 2.75 in.; point angle: 118 deg; helix angle: 29 deg; point grind: crankshaft; clearance: 7 deg; depth of hole: 0.500 in.; cutting fluid: highly sulphurized oil diluted 1:1 with light machine oil; wearland: 0.015 in.

Earthmovers Mark Decade of Progress

A **Decade of Partners in Progress**, theme of the meeting received a resounding welcome from more than 1700 designers, contractors, manufacturers, operators, salesmen, and administrators that attended the 10th Annual Earthmoving Industry Conference. Held April 14 and 15 in Peoria, Ill., the Meeting was sponsored by the SAE Central Illinois Section. The teamwork of those attending the conference, as signified by the large attendance, is truly indicative of a successful "Decade of Partners in Progress." The enthusiasm and vitality ever present in this activity is a tribute to the industry which supports it.

L. B. Greer, Conference Chairman, welcomed the delegates and reviewed the six objectives of the Earthmoving Industry Conference. They are:

1. To publicize the high order of engineering activity in the dedevelopment of earthmoving machinery.
2. To serve the engineers who are locally engaged in designing and developing earthmoving equipment.
3. To bring the younger engineers a meeting of national character.
4. To bring engineers of the Central Illinois area in contact with engineers of wide experience and knowledge in the industry.
5. To promote in younger engineers a desire to belong to a technical society interested in promoting engineering activities.
6. To promote the general welfare of the industry by the publicity to be obtained therefrom.

Banquet speaker, Dr. Carl C. Byers, philosopher, humorist injected a serious thought at the E. I. C. banquet with his Time Out for Laughter presentation. He threaded through his humor the fact that in the everyday seriousness of life we should always take a little time out for laughter. He believes humor is a serious businees and had a message full of fun and philosophy for happy living.

Joseph Gilbert, Assistant General Manager of SAE, presented Central Illinois Section Chairman, Bill Lux, with an anniversary cake commemorating the 10th Annual Earthmoving Industry Conference.

SAE President, Leonard Raymond, stated that his personal goal was to try to improve the quality of the technical papers presented before the Society.

Chairmen for the four technical sessions presented at the Conference were: H. V. Parsley, International Harvester Co.,; J. E. Jass, Caterpillar Tractor Co.; J. H. Hyler, LeTourneau - Westinghouse Co.; and H. H. Washbond, Allis-Chalmers Mfg. Co.

The Conference Committee that administered the details of the 10th Annual Earthmoving Industry Conference was composed of: L. B. Greer, general chairman; J. H. Babbitt, secretary; M. C. Neul, treasurer; L. F. Crystal, program chairman; E. R. Alford, arrangement chairman; Robert Small, housing chairman; R. S. Mills, publicity chairman; and R. M. Edwards, finance chairman.

Capsule descriptions of technical information presented at 10th Annual Earthmoving Industry Conference

"Engineering Mileposts and Horizons in Earthmoving Machinery" — Fred M. Young, Young Radiator Co. The progress and development of earthmoving machinery in the past 25 years has been going on at a rapid pace with much credit due to many technical societies and organizations. With the steady increase in population plus additional government spending, the requirement for more and better machinery will be increasing. With this increased need for better machinery many problems will need close attention from engineers such as excessive corrosion (both direct chemical and electrochemical), improved engine fuels, improvement of en-accessories, improved use of hydraulic equipment, extended use of hydraulic torque converters, and better control of engine temperatures by use of heat exchangers for both lubricating oil and cooling water systems. With the great experience gained from the past, with the aid of the building contractor, and with the capabilities of the earthmoving equipment manufacturers, these many problems will be overcome to meet the needs of the expanding future.

DECADE

OF PARTNERS IN PROGRESS

Torsionally Resilent Drive lines" — P. J. Mazziotti, Dana Corp. The recent increased use of midship mounted transmissions in large equipment has emphasized the need for a torsionally resilient connection from the engine to re-

AT THE SPEAKERS TABLE of the Earthmoving Industry Conference Banquet were: Front Row (left to right) — Leonard Raymond, 1959 SAE President; W. J. Lux, Chairman, SAE Central Illinois Section, Merle R. Yontz, President, Le-Tourneau-Westinghouse Co.; Col. E. O. Davis, U. S. Army Armor Board; W. J. O'Shaughnessy, Design Engineer, Hyster Co.; and Joseph Gilbert, Assistant General Manager, SAE.

Back Row — John G. Mack, Jr., President, Earthmoving Manufacturers Auxiliary; L. Burton Greer, General Chairman, 1959 Earthmoving Industry Conference; D. W. Erskine, Ass't. Chief Engineer, Allis Chalmers Co.; Capt. J. E. Rehler, U. S. Navy; H. S. Eberhard, President, Caterpillar Tractor Co.; and Dr. Carl C. Byers, Banquet Speaker.

duce vibration transfer. Possible sources of torsional excitation in these systems are the nonuniform motion resulting from the firing and compression cycles in a reciprocating engine, misfiring of an engine, impulses from machinery such as compressors, and the nonuniform geometry of a universal joint operating at an angle. To successfully reduce the effect of the disturbing vibratory forces in these systems, the rotating speed of the shaft should be over 1.5 times the natural frequency of the system. (Paper No. S180)

To increase the torsional flexibility needed in these systems the spring rate of the system must be reduced by such constructions as a flexible coupling, a spring loaded damper, or a rubber torsional spring. The rubber torsional spring has proved very satisfactory in these applications. Some considerations in their use are the frequency of load, the load pattern, and the rubber properties. Some advantages of this drive are: it provides an amplitude limitation with impact loads, it provides a cushion to reduce noise and prevents clattering and contacts noises on parts with backlash, it smooths out transition periods to reduce loads on bearings and gears, its clamping characteristics can be adjusted by various rubbers, and its rubber cushion provides a degree of axial flexibility.

"Off Highway Trucks" — L. J. Morgan, M. A. Hanna Co. Large capacity, better performance characteristics, and lower maintenance costs are contributing factors for reducing operating expenses in off-highway trucks. Through the use of high-strength alloy steels the truck box could be made lighter resulting in more pay load-to-tare weight ratio than currently produced.

Tires are the major expense. Nylon cord has helped and it looks as if tubeless tires will be a step in the right direction. Single tires are advocated over duals since the companion tire is immediately 100% overloaded if one of the tires in a dual set goes flat. Too often before the failure is detected, the mate is also lost.

An air-cooled diesel engine capable of meeting the horsepower, performance, weight, and size of present liquid-cooled engines is a much-needed engine improvement. (Paper No. S186)

"Track-Type Tractors" — J. M. Clark, List & Clark Construction Co. Superior performance, versatility, simple construction, and ruggedness are the desirable characteristics of the crawler tractor. Although the crawler tractor is no longer the prime mover of the earthmoving fleet, it is still the leader in performance. This performance must continue to improve to match the tremendous strides being made in the development of the rubber-tired prime movers the crawler tractor is called on to assist. Versatility is no longer the exclusive property of the crawler tractors. Improvements should be sought in the ability to work effectively in mud, rock quarries, rock fills, and on steep, rocky terrain.

A simple, straight-forward design is easy to understand, and a machine that is easily understood is easy to maintain. A greater effort should be made to retain the simplicity of construction and design which has been for

(continued)

Earthmovers Mark Decade of Progress

... continued

so long, characteristic of crawler tractors.

Electrical components, track life, final drives, engine oil filters, air cleaners, torque converter overheating, hydraulic systems, noise reduction, better operator protection, and better stnadardization among competitive manufacturers are the specific needs for development on crawler tractors. (Paper No. S186)

Motor Grader Trends" — H. W. Hartmann, McDougal - Hartmann Co. Higher travel speeds, improved controls, greater capacity, and dependability and economy are needed for a grader to be successful and produce more than its predecessor. (Paper No. S186)

"Giants in Earthmoving" — C. H. German, Midland Electric Coal Corp. Seventy cubic yards are being removed with each shovelfull of overburden in strip mining operations today. To assemble a shovel of this size required 63 carloads of parts and 19 tons of welding rod. The completed machine weighs almost 6 million pounds. 4200 hp is available from the 16 electric motors which are used to power the shovel. (Paper No. S186)

"Evolution of the Scraper" — Elmer Isgren, LeTourneau-Westinghouse Co. From its inception 90 years ago, the scraper has evolved from the horse drawn, wooden, Morman buckboard to the present day rubber-tired, high-speed scraper with positive controls for loading and ejection. The advent of the internal combustion engine was perhaps the biggest single influencing factor in scraper design. The tractor replaced the horse as the prime mover as well as provided power for controlled loading and unloading.

In 1938 a new concept of the tractor-scraper tool made its appearance. This two-wheeled prime mover was an overhung machine that was capable of traveling to the fill and returning at much higher speeds than its tractor drawn counterpart. It was the beginning of high-speed earthmoving as we know it today. (Paper No. S184)

"Radioisotopes and Research" — E. W. Landen and W. P. Evans, Caterpillar Tractor Co. Many tests have been completed by the use of a radioactive material that could not have been determined by normal test equipment Radioisotopes are being used to determine the source of crankcase dilution by the coolant, the distance between double compartments in a tube for a vehicle tire when the compartments are subjected to various pressures, the amount of wear on gears under various speeds and loads, the location of internal defects in castings, forgings, and assemblies, and the leaching of oil from sintered metal bushings. (Paper No. S181)

"Faster and Farther on Earthmover Tires" — D. A. Clendenen, Firestone Tire and Rubber Co. Only a scant 25 years ago the rubber industry was supplying two sizes of off-the-highway tires for short-haul, slow-speed applications. Flotation was their major purpose. Today those original two sizes have grown to more than twenty different size tires that are involved in many operations.

The rubber industry has been confronted with a new problem — that of heat generation on long, high-speed hauls. This particular problem limits the vehicle's speed, the size and weight of the load, and life of the tires. The tire industry is actively engaged in evaluating materials, such as special nylons, wire, and special rubber compounds, and new designs for future off-the-highway tires. However, the earthmoving industry must share the challenge of faster and further on earthmoving tires with a resultant lower cost operation. (Paper No. S185)

"The Often Seen — Seldom Understood Bulldozer" — E. M. Wilson, Caterpillar Tractor Co. The day of the all-purpose bulldozer has passed. Contractors today have to move dirt in the most efficient way possible to remain in this highly competitive business. A specific bulldozer, efficiently designed to handle each type of material, will greatly increase the productivity of the contractor's equipment. (Paper No. S182)

SAE National Meetings

- **August 10-13**

  International West Coast Meeting, Hotel Georgia, Vancouver, B. C., Canada

- **September 14-17**

  National Farm, Construction, and Industrial Machinery Meeting (including production forum and engineering display), Milwaukee Auditorium, Milwaukee, Wis.

- **October 5-10**

  National Aeronautic Meeting (including manufacturing forum and engineering display), The Ambassador, Los Angeles, Calif.

- **October 26-28**

  National Transportation Meeting, La Salle Hotel, Chicago, Ill.

- **October 27-28**

  National Diesel Engine Meeting, La Salle Hotel, Chicago, Ill.

- **October 28-30**

  National Fuels and Lubricants Meeting, La Salle Hotel, Chicago, Ill.

Nuggets from the Iron and Steel Technical Committee

THE bailiwick of ISTC Chairman E. S. Rowland, Timken Roller Bearing's Chief Metallurgical Engineer and 1958 SAE Vice President for Engineering Materials, extends over 32 separate groups. The following news notes reflect ISTC efforts to meet industry needs.

A new ISTC division on properties of ferrous materials at elevated temperatures is being set up as the result of the rapid development of gas turbines which operate at high temperatures. In addition, reciprocating engine temperatures have increased to the point where engine component materials used for valves and exhaust manifolds are a crucial problem.

Information will be developed in the following areas:

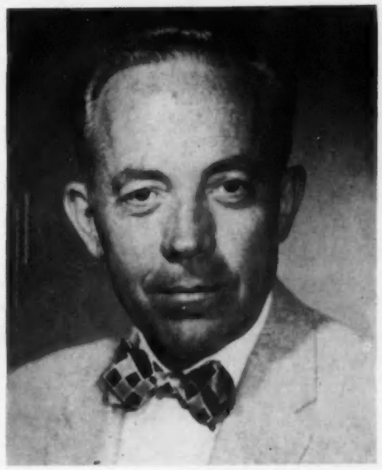
- Classification of families of high temperature ferrous materials.
- Methods of evaluating high temperature properties of ferrous materials.
- How to select ferrous materials for specific high temperature applications.
- Listing of tests which would be useful in making selections of appropriate ferrous materials.
- General information on production procedures.

Since surface texture is becoming more critical due to the tendency to go to thinner automotive paints, Division 32, Carbon Sheet and Strip Steel, is investigating ways of measuring surface texture. They're doing this because . . . when various parts of an automotive body are made of sheets from different coils, it is possible to have an apparent difference in color while using the same paint.

Division 32 has also appointed a special subcommittee to develop an SAE Information Report on the drawability of sheet steel. R. S. Burns, Armco Steel Corp., is chairman.

Surface rolling and related mechanical prestressing treatments will be the subject of a new SAE manual now under development by Division 20, Mechanical Prestressing of Metals. This group is also studying the feasibility of establishing chemical and physical properties of shot.

Along with its work on the machinability rating of carbon steels, Division 11, Machinability, is currently working on ratings for alloy steels and castings. They're also trying to determine industry interest in having ratings for stainless steels.



Dr. E. S. Rowland

An SAE Information Report on chemical and mechanical properties for valve steels is being developed by a Subcommittee of Division 15, Wrought Corrosion Resistant Steels. Subcommittee Chairman R. E. Harvie, GMC's Engineering Center, hopes the group will come up with *a uniform test procedure* for checking valve steels.

Results of extensive research on the behavior of ferrous materials subjected to low temperatures are reflected in the revision of the SAE Information Report on Low Temperature Properties of Ferrous Materials. The report, which was very well received by the ISTC, will appear in the 1960 Handbook. It results from efforts of Division 24, Low Temperature Properties of Ferrous Materials.

Technishorts . . .

F. K. GLYNN, an active participant in SAE Brake Committee work for over 25 years, recently retired from committee membership. In recognition of Mr. Glynn's technical contributions, the Brake Committee passed a resolution commending him for advancing automotive braking knowledge.

REFRACTORY METALS — In recognition of the need for specifications covering refractory metals, the AMS Rocket and Missile Panel is working on specifications for molybdenum, columbium, tungsten, and tantalum. Final consideration of these reports will be made by the AMS Nonferrous Alloys Commodity Committee.

A GUIDE TO BETTER ELECTROPLATING is being developed by the Electroplating Subcommittee of SAE's Nonferrous Metals Committee. Based on an evaluation of plating durability by means of accelerated tests rather than just thickness measurements, the proposed SAE Recommended Practice represents a completely new approach to the development of reliable test methods. According to Subcommittee Chairman D. M. Bigge, Chrysler Corp., thickness measurements will, for the time being, be included in the specification.

SCRAPER NOMENCLATURE — The Construction and Industrial Machinery Technical Committee has come up with a new SAE Standard, Nomenclature-Scrapers. The report was recently approved by the Technical Board for inclusion in the 1960 SAE Handbook.

RADIAL SEAL NOMENCLATURE — The SAE-ASTM Technical Committee on Automotive Rubber have developed a new SAE report on radial seal nomenclature for inclusion in the 1960 SAE Handbook.

MOTOR FUELS — To provide automotive engineers with information on the more pertinent characteristics of motor fuels, the Fuels and Lubricants Technical Committee has formulated a new SAE Information Report on Motor Fuels. The report provides an overall concept of the significant properties of automotive gasolines, and tells where the standard test methods needed to define or evaluate these properties may be found.

Included in the report are sections on antiknock quality, volatility, gum in gasoline, corrosion, gravity, and additives in motor gasolines.

The report is for inclusion in the 1960 SAE Handbook. It will replace SAE's Recommended Practice on Method of Rating Fuels for Detonation.

About SAE Members

Adams

Kohr

Littlewood

JOSEPH E. ADAMS, 1958 SAE vice-president representing Production Activity, has been elected to the new position of executive vice-president for manufacturing and development of White Motor Co. In his new post, Adams will coordinate product research and development, manufacturing, advance engineering, and purchasing activities of all White Motor Divisions. He joined the company in 1944 as production control manager, and became vice-president—manufacturing in 1956.

ROBERT F. KOHR, assistant to the president of Palmer Products Corp., manufacturers of specialty adhesives, has also been named assistant to the vice-president of Colloid Chemical Laboratories, Inc., manufacturers of friction modifying particles. Kohr recently retired as director of Ford's Testing Operations Office (see SAE Journal, December 1958). He was 1956 chairman of SAE's Technical Board; and in 1955 served as SAE vice-president representing Passenger Car Activity.

WILLIAM LITTLEWOOD, American Airlines, Inc.'s vice-president, equipment development, has been appointed chairman of the NASA's Research Advisory Committee on Aircraft Operating Problems. Littlewood was president of SAE in 1954.

CHARLES F. STEVENSON has been named president and general manager of Long Mfg. Co., Ltd., a subsidiary of Borg-Warner Corp.

Stevenson joined Long as purchasing agent when the company was founded in 1932. Subsequently he became sales manager, general manager, and vice-president in 1953. For the past two years he has served as executive vice-president.

EDWARD T. RAGSDALE, a veteran of 36 years with General Motors Corp.'s Buick Motor Division, has retired as general manager of Buick. Ragsdale's service with the Division included the posts of assistant chief engineer, chief engineer and general manufacturing manager, and general manager. He has been a vice-president of General Motors since 1956.

EDWARD D. ROLLERT has been named to succeed Ragsdale as general manager of GMC's Buick Motor Division. He has also been named a vice-president of the company. He joined General Motors in 1934, as a student engineer at the AC Spark Plug Division and held successive positions until becoming assistant works manager of AC in 1943.

In 1948 Rollert was made administrative assistant to the general manager of the New Departure Division; in 1950 was named assistant to the general manager of the Buick-Oldsmobile-Pontiac Assembly Division; and in 1951 was appointed manager of the Kansas City B-O-P Assembly Plant. Since 1955 Rollert has been general manager of the Harrison Radiator Division.

LAWRENCE A. ZWICKER has been appointed to succeed Rollert as general manager of the Harrison Radiator Division of General Motors. Zwicker has been serving as Harrison Radiator Division's director of engineering and sales. He joined the Division in 1929; in 1949 was made assistant chief engineer, and chief engineer in 1956.

CARL A. LINDBLOM has been appointed assistant to the vice-president, engineering, International Harvester Co., in Chicago. As assistant to the vice-president, he will have general authority in all matters pertaining to the company's overall engineering programs. Lindblom has been divisional chief engineer in charge of advanced engineering for IH's Motor Truck Division at Fort Wayne since he joined the company in 1949. He is a member of the SAE Publication Committee.

PAUL J. REEVES has been named vice-president in charge of sales for Timken Roller Bearing Co. Reeves joined the company in 1929 and, since 1951, has been Timken's director of sales.

ROBERT G. WINGERTER, general manager of Timken's Automotive Division since 1955, has been named to replace Reeves as director of sales.

S. G. JOHNSON, formerly assistant manager of engineering for International Harvester Co.'s Motor Truck Division engineering department, has been named manager of engineering for the Division. He had been assistant manager since 1956.

RICHARD C. BRYAN has been named to the newly created post of manager of manufacturing for The White Motor Co. Bryan has been with the company for 11 years, most recently had been division manager of truck assembly and planning.

A. C. SCHLIEWEN has been made works manager for White, also a newly created position. He joined White in 1956 as assistant to the vice-president — manufacturing and, since 1957, has been division manager-truck.

DR. RICHARD H. VALENTINE, formerly chief engineer of General Motors Corp.'s New Departure Division, has been named director of research and development, a newly created post in the Division.

PETER WALLACK has been selected to succeed Valentine in the

Stevenson

E. T. Ragsdale

Rollert

Lindblom

Reeves

Wingerter

chief engineer's post. Formerly he was assistant chief engineer of the Division.

CAPT. JOHN JAY IDE, USNR, is now in Europe where he attended the May conference in Moscow of the International Aeronautic Federation (FAI) — of which he is vice president. He is also attending the International Aviation Salon in Paris this month.

An SAE member for over 32 years, Captain Ide spent over 20 years in Paris as European representative of the NACA, the predecessor of the National Aeronautics and Space Administration.

EVAN S. PRICHARD has been made vice-president in charge of engineering, Cook Bros. Equipment Co. Prichard joined the company in 1949 and has been serving as chief engineer since 1955.

JOHN Z. DeLOREAN, since 1956 director of engineering at General Motors Corp.'s Pontiac Motor Division engineering department, has been named assistant chief engineer of the Division, in charge of advanced design, body, and paint trim sections.

MARK J. GARLICK, formerly assistant chief engineer of Pontiac, has been appointed executive engineer in charge of experimental, quality control, specifications, and production contact sections.

JOHN L. STODDARD has been named to head the newly created Spares organization of Lockheed Aircraft Corp., Georgia Dvision. Formerly Stoddard was field service manager of the Georgia Division facility.

The new organization will coordinate military air depots' and commercial customers' spare parts requirements for the Georgia-built aircraft.

D. S. HARDER, a director and former executive vice-president of Ford Motor Co., has been elected to the board of three Odgen Corp. subsidiaries — Avondale Marine Ways, Inc.; Eimco Corp.; and Teleregister Corp .

ARTHUR E. MILLER, director of research for Scott Aviation Corp., has been selected to head a subcommittee on Air Standards for the Compressed Gas Association Committee on Medical Gases. The purpose of the subcommittee is to establish standards and specifications for compressed air used in underwater breathing equipment, incubators and other respiratory equipment.

Miller is chairman of SAE Committee A-10 on Aircraft Oxygen Equipment.

HUGH HARVEY, formerly aviation supervisor for Shell Oil Co., has been named public relations representative for Shell International Petroleum Co. in London, England.

ROBERT A. HEATH has been appointed manager of engineering of the Warner Electric Brake & Clutch Co. of Beloit, Wisc. Prior to his present post, Heath was chief engineer for the Walker Mfg. Co.

RICHARD T. THORNTON has been named general manufacturing manager of Ford Motor Co.'s Hardware and Accessories Division. Thornton joined Ford in 1934 and most recently had been plant manager, Indianapolis Plant, Transmission and Chassis.

EDWARD A. HASS, president of Columbia River Post, American Ordnance Association, will report on his association's conference, held in Washington, D. C., on "progress toward

Johnson

Bryan

Schliewen

Valentine

Ide

Prichard

DeLorean

Garlick

assuring weapons readiness in the cold war" at an open meeting to be held in the Officers Club at Portland Air Base. He will discuss Army ordnance procurement and how local industry may participate. Hass, a salesman with Ballou & Wright Co., was 1951-52 chairman of SAE Oregon Section.

COL. JOHN P. STAPP, USAF, formerly chief, Aero Medical Field Laboratory at Hollman AFB in New Mex., has been made chief of the Aero Medical Laboratory at Wright Air Developmen Center, Wright-Patterson AFB, Ohio.

THOMAS A. FRISCHMAN, chief metallurgist in the Axle Division of Eaton Mfg. Co. for the past 22 years, has also been appointed chief of quality control for the Division.

In his dual capacity as chief—metallurgy and quality control, Frischman will continue to supervise the metallurgical activities of the Cleveland and Marion, Ohio, plants of the Axle Division, and have direct responsibility over quality and inspection of all components entering into the manufacture of medium and heavy-duty axles for the truck industry.

ROLAND I. STANLEY has rejoined Perfect Circle Corp. as assistant sales manager for the Speedostat Division. Stanley was with the company from 1934 to 1947; since 1952 has been with Walker Mfg. Co. as a sales engineer.

CORNELL JANEWAY has been named vice-president in charge of operations of Janeway Engineering Co., Detroit consulting and development engineers.

Previously he headed the research and development section of American Brake Shoe, Kellogg Division, in Rochester, N. Y.

RENÉ BENDER has joined the staff of "Petroleum Week" as editor, processing and petrochemical section. A graduate of the "Ecole Centrale" of Paris, Bender was editor of "The Sinclair Firebox," which he published in Chicago, and is the author of many magazine articles on petroleum products applications.

WESLEY KLATT has been named manager of engineering records at the Waukesha Motor Co. Klatt joined the company in 1929, and since 1950 has been installations engineer with Waukesha.

CHILDRESS B. GWYN, JR. has been named special projects engineer for the Gibson Electric Co. of Delmont, Pa. Formerly he was technical advisor to engineering, manufacturing, and sales, General Plate Division, Metals and Controls Corp.

WAYNE H. McGLADE has been named product development manager —earthmoving and related equipment, for LeTourneau-Westinghouse Co. McGlade was formerly assistant to the executive vice-president.

McGlade, a member of SAE since 1946, served as chairman of SAE Central Illinois Section's 18th Earthmoving Industry Conference in 1957.

HERBERT H. BOWIE has been made manager of Army relations for Solar Aircraft Co.'s Southeastern District sales office. Bowie has been, formerly, manager of military sales at Lycoming Division, Avco Mfg. Co.'s, Williamsport, Pa. plant.

JAMES R. STROTHER has joined Solar Aircraft Co. as assistant manager, military turbine sales. Prior to his new position, Strother was manager of industrial sales for Flexonics Corp.

ROBERT W. LAING has been made special assistant to manager, Minuteman Research and Development Division, of Aerojet-General Corp.'s solid rocket plant. Prior to this assignment, Laing was manager of design engineering at Ford Motor Co.'s Aircraft Engine Division.

L. B. RAGSDALE has recently been made sales manager of the newly formed sales engineering section of the Ternstedt Division of General Motors Corp. Formerly he was staff engineer in charge of Division's product engineering section.

CHARLES J. GRISWOLD, formerly a senior project engineer of Fisher Body Division of General Motor Corp., has been made assistant engineer-in-charge of design and drafting in the automotive door group.

WILLIAM D. WELLS, has been made senior staff assistant, product engineering activity, for the Fisher Body Division. Previously he was GMC styling liaison engineer.

ROSS W. CHRISTIAN, formerly a senior designer in the product drafting door group, has been named senior project engineer in the product evaluation group.

FRANK C. McMANUS, formerly president of the Anthony Co., has joined the Eagle Crusher Co. of Galion, Ohio, as executive vice-president and general manager.

F. RUPERT GLASS has been appointed manager of the Detroit sales office of Wilkening Mfg. Co. Glass had been with T. W. Moss & Associates as sales engineer.

KENRICK C. PALMER has been made project engineer, Automotive Engineering Department of Standard Oil Co. of Ohio. Formerly, he was structures engineer for Rocketdyne, Division of North American Aviation, Inc.

JOHN E. KELLY is now a retail store manager with GMC Truck and Coach Division, General Motors Corp. Formerly, he was zone manager for GMC Truck and Coach Division.

S. T. CRAWFORD, JR., formerly vice-president of the Crawford Transport Co. has become president of the Sexton Welding Co. Inc.

KARL L. SANDERS is now engineering specialist, preliminary design, with Solar Aircraft Co. Formerly he was technical specialist, preliminary design, with Temco Aircraft Corp.

JOHN W. McGRUER has joined Convair-Astronautics, Division of General Dynamics, as senior field service engineer. Previously he was with Solar Aircraft Co. as project liaison engineer.

OSWALD L. SHARP is now with the Hercules Powder Co. as mechanical engineer in the Salt Lake Air Procurement Office. Previously he was an aeronautical jet engine test engineer at Ford Motor Co.'s Chicago Air Procurement District office.

DONALD E. JAHNCKE has moved from planning and engineering manager of Ford Motor Co.'s Los Angeles Plant to the same position in Ford's Lincoln plant, M-E-L Division, in Wixom, Mich.

FREDERICK A. CRESWICK has joined Battelle Memorial Institute as principal mechanical engineer. Previously he was a research engineer with General Motors Corp.'s Research Laboratories.

MARTIN DRAPKIN, formerly a graduate trainee with Allis-Chalmers Mfg. Co., has been made district office representative for the company in Cleveland.

JOSEPH A. CIPOLLA, formerly manager, engineering laboratory, for McCulloch Motors Corp., has been named systems engineer for Thompson-Ramo-Wooldridge, Inc.

ALBERT E. TERRILL has become senior designer engineer for North American Aviation, Inc. Previously he served as a member of the technical staff of Space Technology Laboratories in Los Angeles.

RONALD J. ROHLOFF has been named sales engineer of Dana Corp. He previously was with L. H. Flaherty Co. as sales engineer in the Western Michigan-Northern Indiana area.

FLOYD F. RECHLIN has been made structures research specialist for the Research and Development Division of Narmco Industries, Inc. Prior to joining Narmco, Rechlin was project engineer with Solar Aircraft Co.

HARVEY S. FIRESTONE, JR., chairman of the board of Firestone Tire & Rubber Co., has been elected national chairman of the United Service Organizations, Inc. (USO) for the ninth year.

FRANKLIN W. KOLK, director of equipment research for American, has been appointed a member of the NASA's Committee on Aircraft Aerodynamics.

GLENN F. KLOIBER has been made research engineer with Rocketdyne, a division of North American Aviation, Inc. Formerly, he was a research engineer for Chicago Stockyards Research Division.

ROBERT B. POGUE, JR., has been named assistant to the president of the American Brakeblok Division of the American Brake Shoe Co. Pogue joined the company in 1950 and most recently had been assistant manager of original equipment sales for the Brakeblok Division.

ALEXANDER BREDE III, formerly director of new product development at Motor Wheel Corp., has become director of research and product development for the company.

A. V. PILLING has been made vice-president, engineering and planning of Aviation Division, Ledkote Products Co. Formerly he served as assistant project manager for Hayes Aircraft Corp.

ROBERT I. WILLIAMS has been made general shop foreman of Kennecott Copper Corp.'s Utah Copper Division. Formerly he was located at the company's Ray Mines Division as pit equipment maintenance foreman.

THOMAS M. DUKES, formerly automotive technical writer with the Paul Marsh Co. of Detroit, has joined the Detroit office of Kenyon & Eckhardt, Inc. as copywriter for the Edsel account.

ERNEST M. MARTIN has become assistant administrative engineer with White Motor Co.'s Autocar Division. Formerly Martin was an engineer with Eimco Corp.

JOHN F. McLEAN, JR. has been made executive assistant to the regional sales manager of Ford Motor Co.'s Midwest Region. Prior to this post, McLean was manager of Ford's heavy truck sales department, Ford Division.

LINUS J. RAUSCH has become manager of the Willow Run Truck Plant in Ypsilanti, Mich., Chevrolet Motor Division, General Motors Corp. Formerly he was manager of the Division's Norwood Assembly Plant in Norwood, Ohio.

R. D. GILSON has been made C-130 project engineer at Lockheed Aircraft Corp.'s Georgia Division. He has been with the company since 1956.

JAMES W. SCOTT has become president of Import Motors of McHenry, McHenry, Ill. Formerly Scott was salesman for Detroit Control Division of American Radiator and Standards Sanitary Corp.

W. EUGENE SINNER has joined Boeing Airplane Co. in weapons systems management. Formerly Sinner was project engineer with Delavan Mfg. Co.

ROBERT J. ROBINSON has joined Coleman Engineering Co. as test engineer, Project SMART. Prior to affiliating with Coleman, Robinson was a test engineer with Stanley Aviation Co.

RALPH W. BISHOP, JR., has become engineer designer B with Industrial Products Division, Boeing Airplane Co. He was formerly research engineer for the research laboratory of General Motors Corp.

LT. COL. ROBERT L. KENDIG has been named chief ARDC liaison officer for the USAF in the Pacific Northwest. Kendig serves as a channel for technical information between HQ Re-

Stapp

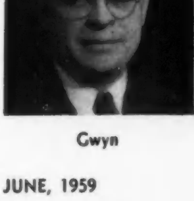
Frischman

Stanley

Janeway

Bender

Klatt



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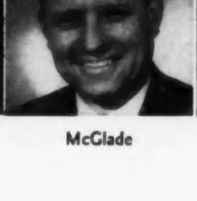
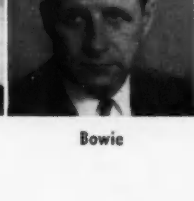


McGlade



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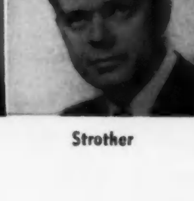

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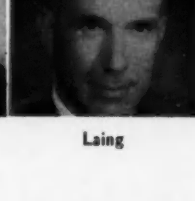

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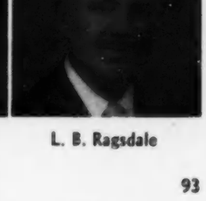

L. B. Ragsdale

About SAE Members . . . continued

search and Development Command, Andrews AFB, universities, and industries in a four state area. Formerly he was assigned to Olmstead AFB in Middletown, Pa., as chief of Plans Division, HQ, MAAMA.

GEORGE R. NOBLE has joined the Radioplane Division of Northrop Aircraft, Inc., as design engineer. Prior to this post, Noble was a junior engineer with the Pacific Division of Bendix Aviation Corp.

RAYMOND H. WILLIAMS has been made vice-president and general manager of Den-Air of New York, Inc. Prior to his new position, Williams was assistant production manager of Dunlop Tire & Rubber Corp.

JOHN H. LETSINGER, has been made assistant manager of engineering for IHC's Division, succeeding Johnson. Since 1957 Letsinger has been divisional chief engineer, product engineering group, Motor Truck Division.

JAMES G. HANNA, formerly district manager of Vickers Inc.'s Chicago office, has been named Western Regional manager for the company's Mobile Hydraulics Division. He will serve a ten state area, with headquarters in El Segundo, Calif.

IKE L. KIBBE has been made project engineer with the Wayne Pump Co. of Salisbury, Md. Formerly he was with E. I. du Pont de Nemours & Co., Inc. as automotive engineer in the Petroleum Chemicals Division.

PAUL JOHN KOLARIK has joined the Boston Woven Hose & Rubber Co. as hose design engineer. Formerly he was junior development engineer for the Goodyear Tire & Rubber Co. in their air suspension design section.

LEO W. TOBIN, JR. has become manager of the Milwaukee operations of AC Spark Plug Division of General Motors Corp. Prior to his new position, Tobin was chief engineer of automotive products for AC Spark Plug Division's Flint operations.

LEONARD EDELSTEIN has joined The Martin Co. as operations supervisor in Denver, Colo. Formerly he was branch engineer for the Radioplane Division of Northrop Aircraft, Inc.

JAMES V. BRADY, formerly design engineer at Minneapolis-Moline Co., is now a design engineer with the engineering department of Caterpillar Tractor Co.

FRANK KRESOWSKI has joined Irving Air Chute Co., Inc. as project engineer. Formerly he was an engine designer with Clinton Engines Corp.

EARLIE S. EVERHART, JR., formerly fire apparatus engineer with Mack Trucks, Inc., has joined Maxim Motor Co. of Middleboro, Mass., as fire apparatus engineer.

PAUL A. GATES, formerly an engineer with Chrysler Corp.'s Missile Division, has joined Sperry Utah Engineering Laboratory as an engineer on guidance and electronic work.

FRED G. BONFILS has been made experimental engineer with General Motors Corp.'s Allison Division. He had formerly been with the Division as supervisor of the test department.

MARTIN I. SILBERG has joined Fairchild Camera and Instrument Corp. as an engineer on aerial camera development. Prior to his new post, Silberg was test engineer, Fairchild Engine Division, Fairchild Engine and Airplane Corp.

JOHN S. YOUNG, has joined the Rocketdyne Division of North American Aviation, Inc. as research engineer. Prior to affiliating with North American, Young was a research engineer with Caterpillar Tractor Co.

E. I. BRICKER has been appointed Division engineer of Lockheed Aircraft Corp.'s Georgia Division Engineering Research Laboratories. He had been department manager, mechanical research department, for the Division.

WILLIAM K. NORWICK, formerly a senior engineer-in-charge of Fisher Body Division, General Motors Corp.'s, engineering shops, has been named to the engineering staff and is now senior engineer-in-charge of the design of seats, underbodies, and general projects.

DEANE F. FLADER is now a design engineer with Grumman Aircraft and Engineering Corp. Formerly, he was a preliminary design engineer for Fairchild Engine Division, Fairchild Engine and Airplane Corp.

JAMES J. CREAMER has become an assistant sales manager in General Motors Corp.'s New Departure Division. He moved to this post, at the GMC's Division home office in Bristol, Conn., from sales zone manager at Cleveland.

BURT L. SMITH, formerly with El Al Israel Airlines, Inc., has joined Lockheed Aircraft Service, Inc., as electrician.

ROBERT W. MARTIN, formerly production manager of the Martin Engineering Co., has become methods engineer of the Norma Hoffman Bearing Corp. of Stamford, Conn.

SIMON H. KAHN has joined Remco Industries, Inc. as junior liaison engineer. Formerly he was a test engineer, junior, with Fairchild Engine Division of Fairchild Engine and Airplane Corp.

JOHN J. FRANZMAN is now manager of the Lubricants Division of the Port Oil Co. Before joining Port Oil, Franzman was lubricants manager of the Crown Central Petroleum Corp.

GEORGE A. BAMFORD has joined FEDER-LINE Truck Bodies, Inc. as sales manager for the Overhead Door Division. Prior to his new post, Bamford was body shop superintendent for the Baltimore Transfer Co., Inc.

A. E. WILLIAMS has become president of the Great Lakes Trailer & Equipment Co., Inc. Formerly he was owner - manager of the Overland Trailer Sales.

DENNIS J. HAYMAN, formerly senior project engineer at Blackhawk Mfg. Co., has become a project engineer with Holley Carburetor Co. of Warren, Mich.

E. M. ARMSTRONG has become Coleman Engineering Co., Inc.'s vice-president — customer relations. Formerly Armstrong was director of customer relations for Air Logistics Corp.

GERALD R. HOLLY, formerly zone sales manager, has been made general supervisor of the specifications and price analysis department, Detroit Diesel Engine Division, General Motors Corp.

WALTER E. HEKALA, formerly project engineer with American M.A.R.C., Inc., is now a mechanical engineer at Norton AFB in San Bernardino, Calif.

JOHN E. ECCLES has joined the General Precision Laboratory in customer service — support planning. Formerly he was supervisor of production for Sperry Gyroscope Co., Division, Sperry Rand Corp.

1959 SAE Transactions Will Include 75 Meetings Papers

THE 1959 edition of SAE Transactions will be published in August. It will include 75 papers presented at Society meetings during 1958 and early 1959.

Prices of the book are: $3 to members, $7 to libraries and U. S. Government agencies, and $10 to nonmembers. Foreign prices are: $3 to members, $8 to libraries, and $11 to nonmembers.

The papers selected by the Readers Committees are:

Steering and Traction Characteristics of Rubber-Tired and Crawler Vehicles — **by W. J. Adams, Jr.**

Riding on Air — **by Hulki Aldikacti, E. W. Anderson, and R. D. Harrison**

New Fluoroester Lubricants for High-Temperature Applications — **by E. C. Ballard and E. E. Sommers**

Engine Pounding — Its Causes and Control — **by J. L. Bame and R. G. Tuell**

The Comprex Diesel Supercharger — **by Max Berchtold**

The Ion Rocket Engine — **by R. H. Boden**

Some Recent Experiments on the Friction, Wear, and Deformation of Solids — **by F. P. Bowden**

Diesel Engines for Use in Light Delivery Vehicle and Taxi Service — **by J. S. Bright**

Optimization Study — Missile Auxiliary Power Systems (as viewed by the equipment supplier) — **by E. I. Brown and R. W. McJones**

A New Look at High-Compression Engines — **by D. F. Caris and E. E. Nelson**

The Behavior of Radiation Resistant ANP Turbine Lubricants — **by J. M. Clark, Jr. and G. C. Lawrason**

Aluminum Die-Cast Cylinder Blocks in Outboard Motors — **by W. C. Conover and R. C. Nelson**

Digital Computer Analysis and Interpretation of Turbocharged Diesel-Engine Performance — **by H. A. Cook**

Routes of Crankcase Oil Loss — **by J. S. Coon and D. E. Loeffler**

Radioactive Tracers Cast New Light on Fuel Distribution — **by D. E. Cooper, R. L. Courtney, and C. A. Hall**

Metallurigcal Developments in Brake Drums — **by V. A. Crosby**

Priming Aids for Cold Starting Diesel Engines — **by J. J. DeCarolis, W. E. Meyer, and P. W. Espenschade**

The Advantages of the New SAE Standard for Involute Splines from a Design Standpoint — **by L. N. DeVos**

Strength and Thermal Limitations of Materials for Airframe Components — **by J. C. Ekvall**

Ion Thrust Engine Development — **by D. L. Eschner**

Rumble — A Deposit Effect at High Compression Ratios — **by A. E. Felt, J. A. Felt, and C. A. Hall**

"Delrin" Acetal Resin, A New Engineering Material — **by H. H. Goodman and J. D. Young**

Indoor Climatic Testing of Automotive Engine Cooling and Air-Conditioning Systems — **by C. V. Hawk and J. W. Godfrey**

Muffler Corrosion — Its Cause and Control — **by R. A. Heath**

GM Diesel's Additional Engines, New Vees and In-Lines — **by K. L. Hulsing and C. E. Ervin**

Knock, Rumble, and Ping — **by H. F. Hostetler and W. R. Tuuri**

Pneumatic Power Control Systems for Trucks, Trailers, and Buses — **by Stephen Johnson, Jr.**

Development of the Suppressor and Thrust Brake for the DC-8 Airplane — **by L. R. Jordan and C. M. Auble**

The Economics of High-Octane Gasolines — **by F. W. Kavanagh, J. R. MacGregor, R. L. Pohl, and M. B. Lawler**

Automatic Transmission Testing — **by H. H. Kehrl, M. R. Marsh, and R. A. Gallant**

The Design of Planetary Gear Trains — **by Oliver K. Kelley**

Iron-Aluminum Base Alloys — Cheap Stainlesses of the Future? — **by Blake King, J. J. Mueller, N. N. Ida, and F. G. Tate**

Ford Free-Piston Engine Development — **by Paul Klotsch**

The Potential of Unconventional Powerplants for Vehicle Propulsion — **by Peter Kyropoulos**

Limited Slip Differentials — **by R. P. Lewis and L. J. O'Brien**

Engagement Characteristics of Wet-Type Clutches — **by L. P. Ludwig**

Starting and Stopping Modern Engines — New Combustion Problems — **by V. F. Massa**

What's New in Brake Linings — **by N. H. McCuen**

How a Diesel Engine Rates Itself — **by W. J. McCulla**

The Buick Flight Pitch Dynaflow — **by Forest McFarland and Charles S. Chapman**

Research in Magnetohydrodynamics — **by William McIlroy**

Status of the SAE S-12 Approach to Vibration Isolation of Aircraft Electronic Equipment — **by Fred Mintz**

An Evaluation of Aftercooling in Turbocharged Diesel-Engine Performance — **by J. E. Mitchell**

Some Observations on the Aging of Low-Carbon Sheet Steel — **by E. R. Morgan**

The Effect of Engine Mounting on Car Shake — **by L. M. Morrish**

Some Aspects of the Operation of Utility Engines — **by E. C. Paige and H. T. Mueller**

Thudding in High Compression Ratio Engines — **by W. E. Morris and D. C. Fariss**

Exhaust Systems, Fundamentals and Design Considerations — **by L. E. Muller**

Possibilities and Problems of Some High Energy Fuels for Aircraft — **by Walter T. Olson**

Knock, Knock — Spark Knock, Wild Ping, or Rumble? — **by R. H. Perry, Jr., and H. V. Lowther**

Simulating Road Shake in the Laboratory — **by K. P. Pettibone**

Single-Cylinder Engine Fuel Research — **by A. W. Pope, Jr.**

Chrysler Corporation's New V-8 Engine — **by R. S. Rarey and E. G. Moeller**

Engineering the "W" Engine, Chevrolet's 348-cu-in. V-8 — **by J. R. Rausch, H. H. Kehrl, and D. H. McPherson**

Practical Design Suggestions for Users of Brazed Honeycomb Sandwich — **by F. F. Rechlin**

How Performance Factors Affect Transmission Design — **by E. A. Richards**

The Use of Bench Wear Tests in Materials Development — **by G. H. Robinson, R. F. Thomson, ad F. J. Webbere**

Investigating Rumble in Single-Cylinder Engines — **by J. A. Robison, M. D. Behrens, and R. G. Mosher**

An Investigation of the Control of Tire Thump by Tire Shape — **by Guy J. Sanders**

Automobile Head-On Collisions, Series II — **by D. M. Severy, J. H. Mathewson, and A. W. Siegel**

Recent Developments Make Engineering Specifications More Realistic — **by Dorian Shainin**

Pyroceram — **by W. W. Shaver and S. D. Stookey**

Dry-Type Air Cleaners on Farm Tractors, A Progress Report — **by J. C. Siemens and J. A. Weber**

The Teracruzer — A High Mobility Vehicle — **by G. D. Simonds**

Aluminum Engines — Design for Modern Fabrication — **by J. M. Smith and R. M. Smith**

Selection of Optimum Modes of Control for Aircraft Engines — **by A. J. Sobey**

Supercharging in the Free-Piston Cycle — **by H. G. Spier**

Theory and Instrumentation of Inertial Navigation Systems — **by J. Statsinger**

Some Thoughts on Optimum Combinations of Wings and Vertical Thrust Generators in VTOL Aircraft — **by W. Z. Stepniewski**

Vehicle Suspensions Using Coil Springs — **by M. C. Turkish**

Now — Practical "Double-Dry" Filtration with Donaclone — **by H. M. Turner and D. K. Anderson**

Design Problems of Very-High-Speed Flight — **by K. E. Van Every**

Thermal Loading and Wall Temperature as Functions of Performance of Turbocharged Compression-ignition Engines — **by E. T. Vincent and N. A. Henein**

New Industrial Tools Utilizing Phosphors — **by C. W. Wallhausen**

If You Squeeze Them, Must They Scream? — **by W. M. Wiese**

Rambling . . .

THROUGH

"Small engines may, **at first glance,** seem not overly impressive, but they present a variety of *large* and complex problems. Customer demands have necessitated as many as 250 crankshaft designs to meet a variety of close coupled end items, and four starting methods for the same models." . . . remarked Wisconsin Motor Corp.'s F. B. Esty at **TWIN CITY SECTION** panel discussion on application problems of small, portable, gasoline engines.

Chet Aggen of Lausen Motors told the Section the story of his company's climb to their present status from the first **15 hp 200-lb engine in 1896** with a 4½" bore and 8" stroke . . . to the light-weight high-performance high-speed engines from 1.2 to 5.5 hp being built today.

Today's modern small engine must be lightweight, yet high-powered, but with a minimum of fancy accessories. However, regardless of these basic requirements, J. H. Budd of the Homelite Division of Textron, Inc., pointed out that these same engines must qualify for high altitude, high environmental demands.

Panel Member Sheldon Pallow, Power Products, outlined how the **development of their new spring wind-up starter** helped overcome cold weather starting headaches. He also warned of the often times over-looked parasitic loads which must be considered in electric starter development.

Panel members, left to right, Sheldon Pallow, sales application engineer, Power Products; J. H. Budd, chief of engine development, Homelite Division, Textron, Inc.; Chet Aggen, chief engineer, Lausen Motors; and F. B. Esty, vice-president and chief engineer, Wisconsin Motors Corp.

JOHN Q. PUBLIC has taken to recreational boating . . . 7,329,000 people now own their own boats. In New England alone there were over 1½ million outboard motors in use by the end of 1958 . . . in the entire country, the 1958 figure reached to something over 5½ million outboard motors in use.

$2,085,000,000 were spent on boating at the retail level in 1958, with over 480,000,000 of this going to purchase of new outboard motors, boats, and boat trailers. The engineering program built around the customer needs and desires for this giant new market was discussed at **SOUTHERN NEW ENGLAND SECTION** in April by Sumner Rice of Johnson Motors Division of Outboard Marine Corp.

MOHAWK-HUDSON SECTION visited the Niagara Mohawk Power Co.'s 400,000 kw generating station in South Albany, N. Y., at their April gathering. Section members inspected four nine-story-high boilers, fired with powered coal, and operated under both forced and induced draft. A stack heat exchanger warms the combustion air and cools the flue gases to less than 200 deg F.

A new fully automatic finishing machine for plug valves, to be used in oil fields, is inspected by members of **TEXAS GULF COAST SECTION** during a tour of Mission Mfg. Co. The engineers visited the 33-year-old firm's recently completed plant in Houston, which manufacturers slush (mud) pumps, percussion drilling equipment, and other oil field specialties. The plant's 162,000 sq. ft. are completely air-conditioned with 1200-tons-output unit; there are no outside windows in the building.

Following the tour, Section members heard Charles O. Bartley, vice-president of manufacturing and engineering of Mission Mfg. Co., discuss the differences between professional societies and unionism.

Seated at **Montreal City Mayor's desk** is SAE President Leonard Raymond, surrounded by a welcoming committee of **MONTREAL SECTION** officers and Montreal's Mayor Sarto Fournier. Left to right are: Section Vice-Chairman Alfred H. Paton; Section Vice-Chairman for Students Guy L. Blian; Mayor Fournier; Raymond; Joseph Gilbert, SAE assistant general manager; Section Past-Chairman J. T. Dyment; and Arrangements Committee Chairman M. J. Bourgault.

THE SECTIONS

SAE President Leonard Raymond, during his presidential touring, met with the **WILLIAMSPORT GROUP** to present his paper on "How Tomorrow's Problems Challenge Today's Research" . . . and to welcome new SAE members E. J. Ounsted, D. I. Jerkins, C. C. Rhoads, T L. Holland, and J. F. Fowler. Raymond (center) discusses his presentation with Group Chairman J. H. Carpenter (left), and A. E. Light, Group Meetings Committee chairman.

Ladies Night at **MID-MICHIGAN SECTION** was April 6 . . . theme of the evening was "The Woman Behind the Man." Festivities included two speakers—Coffee Speaker Mrs. Robert Bates of Kansas City Life Insurance Co. who traced the effects of the feminine influence exerted by the country's First Ladies; and Dr. T. A. Boyd who delivered an address on "My Most Unforgettable Character," drawn from his long years of personal contact with GMC's "Boss" Kettering.

Speaker Boyd (middle) visits with Mr. and Mrs. Glen R. Fitzgerald, (left), and Mr. and Mrs. Forrest McFarland. Fitzgerald is chief engineer, automotive, AC Spark Plug Division of GMC; McFarland is executive assistant chief engineer of GMC's Buick Motor Division.

HAWAII SECTION'S April meeting featured Gilbert Way of Ethyl Corp., discussing both rumble problems in piston engines, and aircraft rocket propulsion. He explained various methods of attacking the rumble problem, including the use of phosphorous in gasoline, and showed movies to demonstrate his talk.

On aircraft rocket propulsion, Way outlined the various systems in use, as well as proposed systems such as the solar-energy rocket.

Speaker Way appears above with (left to right): Section Program Chairman Harry D. Smith; Speaker Way, technical representative, Western Region, Ethyl Corp.; Section Chairman W. J. Maze; and Kenneth M. Watson, supervisor, maintenance, Okau Transport Co., Ltd.

Speaker Stanley W. Burriss is greeted by members of the **SAE KANSAS CITY SECTION** and the Kansas City section of the Institute of Aeronautical Sciences at a joint meeting on "Development of Polaris and Missile Trends." Burriss is weapon system manager in charge of the submarine-launched Polaris ballistic missile project for Lockheed Aircraft Corp.'s Missiles and Space Division.

Left to right are: J. D. Redding, Section Membership Committee chairman; Speaker Burriss (left) shaking hands with A. E. Cocoros, Section vice-chairman; J. R. MacPherson, chairman of IAS section; J. W. Lawton, IAS program chairman; D. W. Berry, chief engineer, Westinghouse Electric Corp.'s Gas Turbine Division; and J. M. Van Dam, Section secretary.

Continued on next page

Rambling . . .

Through the Sections

Continued

INDIANA SECTION engineers inspect a Studebaker Lark on display at their March meeting . . . speaker was E. J. Hardig (left), chief engineer of Studebaker-Packard Corp.; his paper was "A New Dimension in Motoring."

WESTERN MICHIGAN SECTION members met jointly with the Michigan Truckers Association in April . . . topic of discussion was "Fuels and Lubricants." Speaker J. M. Miller (left), director of automotive technical service, Standard Oil Co., gave a summary of recent developments in automotive fuels along with a preview of what can be expected in the near future. Speaker L. A. Wendt (right), senior engineer from Shell Oil Co., discussed many of the problems encountered in engines which are subjected to different types of services, as well as what oil companies are planning to do to overcome these problems.

3M Reinforced Plastic Has Many Applications

Based on talk by

L. A. HEGGERNESS

Minnesota Mining & Mfg. Co.

(Presented before SAE Southern New England Section)

THERE are available today to the designer and fabricator in any industry, reinforced plastics in forms that will most satisfactorily suit each specific problem. The orientations of the fiber can be varied. The size of the sheet or roll and its thickness can be adjusted and the resin matrix can be made to suit the need. Performance levels and uniformity of quality are a reality.

One of these is "Scotchply" brand reinforced plastic — a pre-impregnated thermosetting epoxy resin with continuous glass filaments. It is primarily a high-strength material in direct competition with the ferrous and nonferrous metals.

It has successfully replaced steel in such applications as a flat leaf spring employed in vibratory conveyors and screens. The reasons include the following:

- Fatigue life — being amorphous rather than crystalline, if properly designed it should never fail from fatigue.
- Yield point — material has no yield point, for all practical purposes: that is, ultimate strength and yield point are the same.
- Not notch sensitive, whereas metals will progress.
- Corrosion resistance.
- High ultimate strength to low modulus, which permits use of a single leaf in most cases, replacing the bundles of steel. This eliminates packing and abrasion action between leaves.

The spring is a perfect example of an engineered product where the physical properties were utilized to the fullest. The secret is to orient the fibers in the direction of greatest stress. In this case the longitudinal direction has greatest stress.

Other applications include its use in refrigerated box cars made for the Rock Island and ACF, landing gear for Cessna Aircraft, helicopter blades for Kaman Aircraft, bumpers and automobile tops for Ford cars.

What about the Future?

The high cost of raw materials has been a definite disadvantage but, as volume increases, costs will be proportionately decreased. It's pretty rough sledding nowadays to push a \$2 a pound material against steel at 20–30¢ a pound or aluminum at 50–60¢ a pound.

Here are a few of our items:

1. Laminates that will give a modulus in the range of 8–10 million, with flexure strengths of over 200,000 psi.
2. Ablation materials used primarily in missile reentry vehicles, where resistance to extreme temperature for a few seconds is necessary. Phenolic resins reinforced with such fibers as Refrasil, Amersil, quartz (which sells for \$185 per lb), asbestos, or nylon are now considered standard materials.
3. Molding compound — if its price could be reduced from over \$3 per lb to half that, it would have a tremendous future.

To go way out on Cloud 9, it is not outside the realm of possibility that, within 10 years, complete automobile bodies will be made of reinforced plastic. A complete redesign would be necessary. High stress areas would have to be "beefed up" with a high strength plastic. The top and the bumpers would be an integral part of the body shell. Corrosion would never again be a problem and color would be permanently impregnated into the plastic. Also, because yield strength of the material is so high, minor accidents, which cause dents and scratches on present-day automobiles, would have no effect. Better gas mileage would result from the lighter weight.

Control Methods Check Vendor Parts

Based on report by secretary

J. J. RYAN

General Motors Corp.

TO CONTROL vendor automotive-part quality, four methods are in general use today. These are:

1. **Pilot Plant or Control Plant** — The receiving inspection is intensive under this method. A shipment of parts from each vendor is received and reports of these shipments are sent to the "home" plant and to other assembly plants serviced by the control plant. This method works nicely until the unscrupulous vendor becomes aware of the plant being used as the control plant and begins to send hand-picked shipments to that plant and run-of-the-mill products to other plants.

2. **Home Plant Control System** — This functions the same as the Control Plant Method, but has the advantage of being cheaper to operate because it is unnecessary to duplicate gages and inspection personnel. Its shortcomings, however, are the same as the Control Plant Method.

3. **Lot Shipment Plan** — This plan is based on the principles of sampling inspection of large lots. All shipments from vendors to assembly plants are assigned lot shipment numbers. When shipment of these lots is made to assembly plants, a sample of the shipment is shipped to the home plant for inspection purposes and the individual assembly plants are sent copies of receiving inspection and laboratory reports. If, however, an assembly plant finds itself in difficulty with parts that have been approved by the home plant, notification of this defect, by lot shipment number, is sent to all plants to remove that shipment from the assembly line.

4. **Resident Inspectors** — The plan of having a resident inspector in a vendor's plant, or to cover numerous vendors' plants, within a geographical area, is almost financially impossible. This method is based on the military methods of World War II. Though the method is not commonly used, an outgrowth of it is practiced by some manufacturers on some highly critical parts such as safety items. This outgrowth is sometimes called certification of a vendor. Upon receipt of a bid from a new vendor by the purchasing department, inspection or quality control personnel, accompanied by process engineers, make a survey of the vendor's plant. This survey will include such items as: philosophy of the management, the organization of the production versus inspection departments, the tooling to be used in manufacture, the processes to be used, production and inspection gaging, the available gage-room facilities, and the types of inspection gages used and methods of control of quality. A numerical evaluation of each vendor is used as one of the criteria in awarding a contract for the manufacture of a given part or parts.

All of the above methods have their merits and their shortcomings. However, no matter which method is used, the most important single item that must be produced from each is "obtain the facts." Without facts, pure facts, no accurate and factual decisions can be made. This is an area that statistical quality control can aid in, as well as in the area of reduction of these facts by the statistician into concise and usable form for management's use in making decisions.

Serving on the panel which developed the information in this article, in addition to the panel secretary, were: **B. E. Starr**, General Motors Corp.; **H. C. MacDowell**, Chrysler Corp.; **J. T. Welsh**, Sheffield Corp.; **W. E. Swigart**, Ford Motor Co.; and **J. C. Miller**, General Motors Corp.

(This article is based on a secretary's report of a production panel entitled "Economy of Correcting Assembly Troubles at the Source." This report — along with 8 other secretaries' reports on various production subjects — is available in multilith form as SP-326. See order blank on p. 6.)

Glass-Ceramics Promise Varied Uses

Based on paper by

GEORGE W. McLELLAN

Corning Glass Works

(Presented before SAE Buffalo Section)

PYROCERAM, a new glass-ceramic material, has properties that suggest its use for bearings, spacer and seal rings, piston tops, and valves. It is stronger than glass and higher in surface hardness. It is opaque, has high electrical resistance, can be formed in many shapes and sizes, and can be finished to precise tolerances.

The mechanical, electrical, and thermal properties of two Pyroceram compositions are shown in Table 1. The low thermal expansion coefficient of composition 9608 coupled with its ability to be finished with a precise polished surface suggests its use for surface plates and gage blocks.

Fig. 1 shows a seal ring and ball bearing with Pyroceram wearing surfaces. Such ball bearings have withstood temperatures as high as 1800 F and as low as – 200 F. They function with or without lubricant with little wear or increase in friction coefficient. Moreover, they can operate in corrosive liquids with less deterioration than a metal bearing. Although still in the stage of development, these bearings give promise of extending the environmental condition in which bearings can be used.

When this glass-ceramic is used as a piston top, it provides a nonfouling surface which will keep combustion conditions constant in the cylinder. And because of its relatively low thermal conductivity, the top will reach and maintain a higher temperature than a metal piston.

To Order Paper No. S189 . . . on which this article is based, see p. 6.

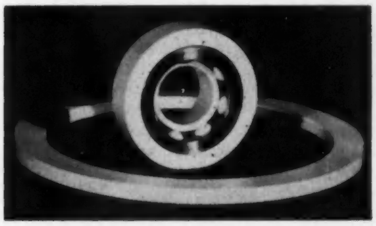

Fig. 1 — Seal ring and ball bearing with Pyroceram wearing surface.

Table 1 — Properties of Pyroceram Composition

	Composition No.	
	9606	9608
Specific Gravity at 77 F	2.60	2.50
Water Absorption	0.00	0.00
Porosity	Gas	tight
Upper Operating Temperature, F	1300	1300
Mean Specific Heat over 77–750 F	0.230	0.235
Thermal Conductivity at 77 F, Btu/hr-ft-deg F	2.10	1.13
Linear Coefficient of Thermal Expansion over 77–570 F, 10^{-6}/deg F	3.17	0.30 – 1.10
Modulus of Elasticity, 10^6 psi	17.3	12.5
Modulus of Rupture (Abraded) (103 Psi)	20.0	16 – 23
Hardness (Knoop 500 G)	619	588
Log_{10} Volume Resistivity, ohm-cm		
At 482 F	10	8.1
At 672 F	8.6	6.8

Radioisotopes Aid Surface Phenomena Studies

Reported by

R. C. Wiquist
Chrysler Corp.

A feature of the SAE Nuclear Energy Advisory Committee

RADIOISOTOPIC techniques for studying surface phenomena include use of:

- Activated parts to allow continuous and simultaneous detection of wear.
- Tagged components in fuels, lubricants, and their additives; and in surface coatings.
- Tracers to detect elements having no radioactive isotopes.

These techniques are helping us understand and improve engines by providing methods for:

- Determining part wear and material transfer.
- Determining the function of fuel and lubricant additives.
- Elimination of objectionable deposits due to additives.
- Studying the nature of surface structure.

Activated Parts

Wear of piston rings was investigated almost two decades ago by Ferris.[1] Since then the development of the reactor for nuclear activation and the development of advanced scintillation techniques permit the continuous and simultaneous detection of iron and chromium wear from piston rings for the evaluation of effects of fuel and lubricant additives on wear.[2] Radioactive gears have also been used in wear studies.[3,4] The use of an activated part such as a radioactive piston ring or gear permits a continuous wear measurement of a single part without the necessity of intermediate disassembly. The high sensitivity of the tracer technique permits determination of microgram quantities, and hence short test runs can be used.

Activation analysis in reactors and cyclotrons has permitted the detection of over 60 elements.[5] Recent adoption of the activation technique now permits determination of a particular part responsible for wear in an engine.[6] Wear tests are run with no radioactivity, but wear particles are filtered, collected, and activated. By analyzing the induced radioactivity, the parts responsible for the wear can be detected if their initial compositions are unique in containing some element.

A radiotracer technique that can be used to determine surface films and deposits is based on the absorption properties of the radiation emitted from radioactive isotopes. Fries et al[7] have described how a radioactive plug can be used to measure engine deposits.

Radioactive Tagging

The surface study technique that has perhaps the greatest potential for investigations is the use of a tagged component in fuels and lubricants or in their additives. For example, radioactive tetraethyl lead has been used to study the distribution of lead deposit formation on internal engine surfaces.[8] The use of radioactive sulfur and phosphorus in the extreme-pressure oil additive, zinc dialkyl dithiophosphate, has shown that a protective additive film is formed on cam and tappet surfaces, and that this film formation is directly related to contact temperature and pressure between the mating surfaces.[9]

Plated metals, as well as surface coatings, such as phosphating, can be tagged with a radioactive component enabling surface studies of wear, metal transfer, exchange reactions,[10,11] passivity, and location of surface inhomogeneities.

Detecting Elements Having No Radioisotopes

The previously mentioned studies have employed either a radioactive part or a radioactive tracer in a material that normally contacts or is applied to a surface. However, there are elements having no radioactive isotopes suitable to use as a tracer. This does not prevent the use of tracers, however. One need only find a radioactive material that will selectively react and label the particular component. Both liquid and gaseous radioactive materials have been used to label specific material. Rabinowicz[12] used radioactive amyl iodide to locate the distribution of copper transferred to steel in friction studies. Recently, hydrogen sulfide (radioactive sulfur) has been used to determine porosity of titanium dioxide on aluminum and of chromium on iron.[13]

The application of radioactive tracers to surface studies, especially under dynamic operating conditions, is of particular interest to the engineer. Nevertheless, there has been some hesitation to study dynamic surfaces because conventional counting techniques are not, in general, suitable for determining variations of activities on curved surfaces. However, autoradiographic techniques have advanced so that quantitative results can be obtained on curved surfaces. Present investigators have found that these techniques complement each other.

Additional Aids

The Isotope Index[14] is a valuable aid to finding the sources of commercially available tagged compounds. Excellent periodic review articles in *Analytical Chemistry*[15] and the *International Journal of Applied Radiation and Isotopes* aid in keeping the investigation up to date. The radioactive isotopes are available; the detection techniques and instrumentation are available; only the imagination and effort of the individual investigator are required.

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1 U. S. Patent 2,315,845, "Wear Test Method and Composition," issued to S. W. Ferris, April 6, 1943. Assigned to Atlantic Refining Co.

2 "Radiotracer Technique Probes Adhesive Wear of Rings," by R. Abowd, Jr. *SAE Journal*, Vol. 67, March 1959, pp. 67-68.

3 "Wear Rates of Gears by Radioactive Method," by F. L. Schwartz and R. H. Eaton. Presented at SAE National Tractor Meeting, Milwaukee, September 1954.

4 "Studies of Formation and Behavior of Extreme-Pressure Film," by V. N. Borsoff and C. W. Wagner. *Lubrication Engineering*, Vol. 13, February 1957, pp. 91-99.

5 "Nuclear Irradiation and Radioisotopes in Metal Research," by M. T. Simnad. *International Journal of Applied Radiation and Isotopes*, Vol. 1, November 1956, pp. 145-171.

6 "Use of Activation in Making Isotope Techniques More Available to Industry," by W. W. Schultz, H. B. Briggs, R. A. Dewes, E. E. Goodale, D. H. Morley, J. P. Neissel, R. S. Rochin, and V. V. Verbinski. Paper P819, presented at 1958 Atoms for Peace Conference, Geneva, September 1958.

7 Radioactive Deposit Gage for Engines," by B. A. Fries, J. G. Mingle, and H. W. Sigworth. *International Journal of Applied Radiation and Isotopes*, Vol. 1, January 1957, pp. 270-275.

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Power Adequate for Rocket Vehicles

Based on talk by **RICHARD B. MORRISON,** University of Michigan

ROCKET powerplants can supply sufficient power in an economical package to provide satellite and escape vehicles of infinite range. Nevertheless, one might still ask what limits are imposed on rockets. Some of the chemical rocket limits can be appreciated from the following equation:

$$V_{ex} = \sqrt{\frac{2\gamma R T_c}{M(\gamma - 1)}\left[1 - \frac{P_{ex}}{P_c}^{\gamma - 1/\gamma}\right]}$$

For large chamber pressures, the factor T_c/M is controlling where:

V_{ex} = Exhaust velocity
R = Gas constant
M = Molecular weight
γ = Ratio of specific heats
T_c = Chamber temperature
P_{ex} = Exhaust pressure
P_c = Chamber pressure

The availability of specific impulse from chemical combinations up to and in excess of 350 sec is indicated in Table 1. The price tends, however, to increase with high energy propellants.

Table 1 — Specific Impulse of Missile Propellants
(500 psia chamber pressure)

Oxidizer	Fuel	Chamber Temperature, F	Molecular Weight	c_p/c_v	I_{sp}, sec
Hydrogen peroxide	Gasoline	4830	21	1.20	248
Hydrogen peroxide	Hydrazine	4690	19	1.22	262
Nitric acid	Gasoline	5150	25	1.23	240
Nitric acid	Aniline	5100			235
Nitric acid	Ammonia	4220	21	1.24	237
Oxygen	Alcohol	5560	22	1.22	259
Oxygen	Gasoline	5770	22	1.24	264
Oxygen	Hydrazine	5370	18	1.25	280
Oxygen	Hydrogen	4500	9.0	1.26	364
Fluorine	Ammonia	7224	19	1.33	306
Fluorine	Hydrazine	7940	19	1.33	316
Fluorine	Hydrogen	5100	8.9	1.33	373

Combustion-Type Fuels For Thrust Vehicles

Based on talk by

WARREN E. WOODS
Petroleum Products Division,
Continental Oil Co.

(Presented before SAE Wichita Section)

THERE are many types of thrust vehicles and even within a given type there is considerable variation in suitable fuels. For a variety of reasons I would prefer to discuss the subject more in terms of general principles and historical trends. Further, I would like to restrict myself largely to combustion-type fuels rather than the more exotic means of propulsion such as photon drives.

In any system using chemical combustion, the fuel is chemically reacted with an oxidizer to form a large volume of hot gas. This hot gas provides the thrust necessary to operate the vehicle. For example, in the piston engine which is not truly a thrust engine, a mixture of gasoline vapor and air is ignited. A large volume of hot gas is produced which forces the piston down and imparts rotational motion to the crankshaft. In many ways, a similar system is used in true thrust engines. For example in the familiar turbojet, a supply of jet fuel is mixed with compressed air and burned. Part of the energy in the exhaust of hot gas is used to drive the compressor but the bulk of the energy is obtained by exhausting the hot gas. This type of engine, of course, is used in the Boeing 707 and Douglas DC-8. A somewhat similar version is the turboprop engine which employs a propeller shaft geared to the turbine shaft. Here most of the energy is absorbed in the turbine and only a minor amount of thrust is obtained. In the liquid bipropellant rocket, you have two tanks, one containing fuel and the other oxidizer. These are mixed and combustion occurs, again giving large volumes of hot gas. In somewhat similar solid propelled rockets, the fuel and oxidizer are premixed and combustion usually starts from the interior of the solid grain and works outward toward the case.

Regardless of the form of the hardware, the mechanics involved are the same. The basic principle is that of conservation of momentum. In other words, the mass of the exhaust gas times its change in velocity must be equal to the mass of the velocity times its change in velocity so that the push or thrust obtained depends on how much hot gas you are making and what its velocity is. The velocity in turn is related to the temperature of the exhaust gas and inversely related to the molecular weight of this gas. Again the maximum temperature is controlled by the heat of the combustion in the fuel and the specific heat of the exhaust products. What this means is that overall the thrust per pound of fuel used is equal to the heat of combustion divided by the molecular weight and the specific heat of the exhaust products.

Now usually this term, "thrust per pound of fuel," is not used in rocket work since the primary consideration is thrust obtained per pound of fuel and oxidizer. The rocket, of course, carries both fuel and oxidizer in contrast to the turbojet which picks up its own oxidizer from the surrounding air. Hence, in rockets the controlling factor is specific impulse which is defined as the pounds of thrust obtained by burning one pound of propellant per second.

For those of you who are not familiar with the critical nature of specific impulse, this next chart shows the theoretical range obtainable at various specific impulses. These figures apply to a single stage rocket with a 10:1 ratio; that is, the rocket weighs ten times as much at takeoff as at burnout. At specific impulse of 200, the theoretical horizontal range is around 1300 miles. For specific impulse at 300, the range is increased to 4750 miles. For a specific impulse of 400, the empty rocket can be placed in satellite orbit. At 500, and above, such a rocket can reach escape velocity and escape from the earth's gravitational field.

Where we now stand on specific impulse can be seen from the following chart. Starting in 1942 with propellants taken from German experience, such as nitric acid as an oxidizer and alcohol fuel, we had a specific impulse of around 200. By 1956, we had raised this to about 250 using liquid oxygen in jet fuel. In 1958, we were approximately 300 using liquid oxygen and dimethyl hydrazine. The likely limit in the foreseeable future is around 340 which will probably be achieved with liquid fluorine as an oxidizer and hydrazine as a fuel. Both of these ingredients are difficult but not impossible to handle. The theoretical limit is somewhat higher, around 375 using fluorine and hydrogen. It is doubtful is this limit is ever achieved because of difficulties in hydrogen liquefaction.

There are of course a number of Buck Roger possibilities. For example, using an atomic pile as a source of heat and hydrogen as a working fluid. This would give specific impulse in the neighborhood of 900. Recombination of isolated free radicals might give specific impulse in the neighborhood of 1800. For outer space work it is conceivable that we might get to specific impulses of 20,000 using a cesium ion beam produced by a reactor in space. These latter possibilities

are not outside the realm of probability and in fact all three are being worked on actively under government auspices. Nevertheless, before the next few years and presumably an even longer period, we will continue to use normal chemical combustion fuels.

More recently we started extensive work on solid propellants. The normal type has been a mixture of some polymer such as Thiokol rubber and an oxidizer such as ammonium nitrate. This would give specific impulse in the neighborhood of 200. Other more advanced solids use boranes as fuel and ammonium perchlorate as oxidizer. Recently Olin Mathieson has announced a solid propellant in the 265–300 range.

It may look a little peculiar that we have an active interest in solids despite the higher specific impulse obtainable with liquids. The first reason for this trend is military interest in storable, simple, and highly reliable vehicles. As an example of this trend, I might cite the Army's experience. The Army, of course, started with missiles, such as the Corporal, which were patterned on a German development. They were developing a whole family of such missiles, such as the Redstone, the Jupiter C and others at the time the overpowering need for reliable weapons in military operations became clear. The more recent military missiles are almost without exception solid propellants. For example, we have the Dart which is a very short-range and a tank missile. The Lacrosse which is a substitute for artillery and the Honest John and the Little John which both have sufficient range for nuclear warheads, and the Sergeant which again is a nuclear weapon. More recently the Army has announced intent to replace the Redstone with two solid propellant missiles, at least originally to be called Pershings. One version is a single stage missile of about 500 miles range and the other a two-stage missile with a range of about 1500 miles. Paralleling these developments in Army missiles are similar changes occurring in Air Force and Navy weapons. I believe you have all heard of the Polaris, the Navy's solid fuel ICBM. Similarly, the vast missile complex known as the Minuteman will use solid fuels. This system is, of course, designed for pushbutton underground installations within the continental U. S.

There is still a place, however, for liquid propellants, particularly in space applications. The probable rocket fuels of the future are indicated on this next chart. We have, of course, used as oxidizers, red fuming nitric acid in a number of our missiles, such as the Nike Ajax and the Corporal. Liquid oxygen is widely used at this time and will probably continue. However, our prediction is that it will be supplanted by liquid fluorine. In the solid oxidizer, the trend is from the old standby ammonium nitrate to lithium perchlorate. These of course will find wide usage in military weapons.

As far as fuels are concerned, both RP1, which is a special kerosine, and dimethyl hydrazine are used widely and probably will be continued for sometime. Other fuels in which there is growing interest are aluminum alkyls, boron alkyls, the liquid boron hydrides and possibly, though remotely, the ultimate in energy — liquid hydrogen. In solid fuels the rubbery polymers will probably be eventually replaced by the more energetic solid boron hydrides. A number of these fuels are also suitable for special application in ramjets rather than rockets. For example, both the aluminum alkyls and boron alkyls ignite spontaneously on contact with air and burn at rates several times those encountered with hydrocarbons. The boron hydrides could also conceivably be used in ramjets but the big disadvantage is cost. For example, one of the present methods of manufacturing boron hydride is shown on this chart. Generally the raw materials are a reactive metal such as sodium, hydrogen, and some source of boron. By a series of rather complex reactions a very poisonous gas, diborane, is obtained. This gas is the prime intermediate used in manufacture of all boron hydride fuels. It can be polymerized or alkylated to yield a variety of products ranging from liquids, such as ethyl pentaborane, to solids, such as decaborane. The cost, however, is very much greater than any other fuel now in existence. Despite this inherent cost which is unlikely to be reduced below $2.00/lb, there have been a number of plants erected under government subsidy. Investment today in such plants is in excess of 100 million dollars. These plants will have very limited production capacity and will suffice only for production for enough fuel for weapons development. Should we be forced into this type of fuel by its performance advantages, there will have to be a major construction program in the U. S., at an astronomical cost.

Regardless of how good any of the present fuels look, it is a sure bet that we will see other and better fuels in the future. Many industrial firms, including oil companies, are actively working on the development of new fuels. Most of this work is in the area of boron compounds and metal alkyls which is almost virgin territory for American industry.

5 Computer Programs At Ford's M-E-L Division

Based on paper by

J. E. ZIMMERMAN,

M-E-L Division, Ford Motor Co.

FIVE computer programs in use at Ford's M-E-L Division provide a variety of important data to increase the speed and efficiency of operating schedules and processes. As a direct result of the time savings, analysis of customer order data is now incorporated into manufacturing scheduling.

Program 1, the daily schedule control, gives those at the General Office production to date and a forecast of what the production off the line will be one week in advance of production.

Program 2 permits analysis of advance copies of orders at the sales districts and at the assembly plants that have not yet been given to Manufacturing. These are analyzed twice a month into schedule codes and the data projected statistically as the basis of expectations of what is going to be built after the one-week projection of Program 1.

Program 3 is the plant building schedule for the next six months. It computes what has been built through the model year and monthly figures for each of the next six months for each of the 700 schedule codes and for each plant. The immediate near term schedule feeds back into Program 1, establishing a new cumulative through the model year and daily schedule.

Program 4 computes what and when the vendor is to ship, what the vendor is to fabricate, and what can be given him for planning volumes for future months.

Program 5, plant inventory control, is yet to be completed. It will receive as input various data from the other programs, as well as parts receiving data at the assembly plants. This will make it possible to ascertain on a part-by-part basis whether or not the plans laid in the plant building schedule are being carried out in so far as parts availability at the assembly line is concerned.

The time savings brought about by these five computer programs have been accompanied by more accurate data and reduced costs.

To Order Paper No. 39U ...
on which this article is based, see p. 6.

Fuel Properties Affect Jet Transport Design and Operation

Based on a paper by

FRED K. BRUNTON
and
JOSEPH C. DeWEESE
Boeing Airplane Co.

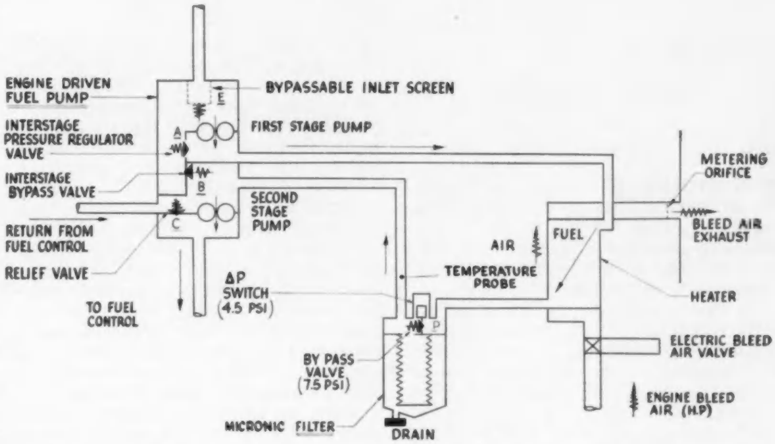

Fig. 1 — Heater-filter system which directs warm engine bleed air into fuel tanks, melting collected ice.

JET FUEL PROPERTIES have had marked effects on jet transport design and operation. These effects result from the high fueling costs, which have forced engine manufacturers to restrict requirements to fuels available on a worldwide basis — JP-4 and kerosene.

Because fuel tanks are never completely free of water, for example, heater-filter systems have been designed to combat the adverse effects of water solubility on the fuels. One such device, developed by Pratt and Whitney Aircraft, has a pressure drop switch which closes when the ice buildup on the filter reaches a predetermined amount. A signal then lights in the cockpit. The fuel is heated when a crew member throws a filter de-ice switch, directing high-temperature bleed air through the heater's air passages. When the fuel is warm enough to melt the ice and eliminate the pressure drop, the light goes out. The device is shown schematically in Fig. 1.

Most of the jet transport operation to date has been on kerosene-type fuel having a freezing point of − 50 C. During December 1958, Pan American crews kept minimum fuel temperature data for each flight. The lowest ambient static air temperature recorded was − 68 C. Seventy-eight per cent of the flights of over 3-hr duration experienced air temperatures of − 50 C or below. The lowest recorded fuel temperature was − 38 C, which is 12 C above the specification fuel freezing point. The operator must carefully analyze his flight plans when selecting a fuel, considering minimum expected temperature and time factors.

Vent systems, too, have to be designed to compensate for certain fuel characteristics. Those of the jet transport, for instance, are set up to handle any liquid fuel flow during refueling, which is more than sufficient capacity to handle any vapor that forms. The low vapor pressure of kerosene (0.15 psi) means that no fuel losses due to boiling will occur in the operating regime of any initial fuel temperature.

The refueling operation has revealed electrical faults within the fuel gaging system. This system is used to determine the fuel quantity in each tank prior to refueling and is monitored during the refueling operation. The basic geometry changes between flight and ground conditions of the swept-wing airplane and unlevel ramps at refueling position have resulted in inaccurate fuel quantity indications during fueling. Correction curves were devised so that the indicated quantity readings accounted for actual ramp attitude. However, level fueling ramps are needed to gain maximum refueling efficiency and accuracy.

Several factors affect the choice of fuel for jet transports, for example:

1. The lower rate of flame spread in liquid kerosene offers crash survival possibilities over JP-4. Kerosene fuel sprays are highly flammable, but rarely accompany an otherwise survivable crash.

2. A fuel's heat of combustion affects the airplane's range and, therefore, the cost of fuel. The volume-limited plane can fly farther with fuel having the most Btu per gallon, while a weight-limited plane achieves maximum range on a fuel with the most Btu per pound. The jet transport has sufficient tank volume so that it is never volume-limited when loaded to maximum payload. The operator must make careful analyses of his costs to determine which fuel meets his needs most economically.

To Order Paper No. 47R . . . on which this article is based, see p. 6.

Computer Controls Parts Distribution

Based on paper by

BOYD ZACHARIAS

General Motors Corp.

CHEVROLET has recently installed an IBM 705 Electronic Data-Processing Machine for the control of production, processing, warehousing, and distribution of over 50,000 different automobile parts and accessories.

A new system, designed around the 705, eliminates much former manual handling by combining zone inventory information in a centralized record with major supply depot inventory records.

Punched paper tapes are airmailed from each zone warehouse, daily, to the central processing center in Flint. These paper tapes are recorded on magnetic tape by an IBM converter. It is then possible to process these inventory transactions on the 705, combining this information with previous balance-forward information, which is also on magnetic tape, to develop a new record with up-to-date balances.

Although the 705 performs this updating rapidly, this is perhaps the least important function in this operation. The important thing is that, while the updating is being done, the 705 is also making important decisions regarding the actual movement of parts from factory or supplier to supply depots and to the zone warehouses.

These decisions are excellent examples of "management by exception". The 705 decides when action is necessary, prints the documents necessary to effect such action, and permits a visual audit of that action. If the machine decides no action is necessary, no action is taken.

As warehouse balances are updated each day, the machine recomputes warehouse requirements based on sales history of the prior four weeks. This variable requirement, called the "progressive bank", allows time for replenishment shipments to arrive before stock has been depleted, and is designed to make the most economic use of warehouse space.

As the bank is computed for a part for a particular warehouse, it is compared to the balance on hand. If the warehouse balance is less than the computed bank this information is automatically transferred to a set of instructions which then computes the number of parts to be shipped.

Involved in this calculation is a section of the master record which shows standard packaging quantities, enabling the computer to order parts in packages containing a specified number of units. The bank, the current balance, and standard packaging, or unitizing, all enter into the calculation of the shipping quantity. When these calculations have been completed (a fraction of a second) the results are recorded on a special magnetic tape which will subsequently write the shipping orders for the transfer of material to the zone warehouse from the major supply depots.

Similarly, the supply depot stock is watched electronically, and advice forwarded to buyers for procurement action when necessary. In addition, in analyzing new stock balances, decisions are made when emergency action is required. Not only are cases of zero balances or near-zero balances brought to light, but the 705 determines from what zone warehouse an emergency transfer may be made to alleviate the condition until the effect of normal replacement action is realized.

Benefits expected from this system in the near future include:

1. The procurement, distribution, and control of containers and other parts packaging materials. These items represent a large cost factor in overall operations, and are of importance not only from a procurement and replenishment point of view, but also as a distribution problem. Additional programming will help reduce the capital investment in such items, and yet have them available when and where required.

2. Parts reclassification and excess stock analysis. Programming in this area will permit the use of the 705 in periodic special analyses of the master record to re-evaluate the classification of parts based on past sales, to determine the proper stocking point and other similar factors.

3. Warehouse bin sizing and rearrangement. By carrying in the master record package sizes of each part, studies will be made possible wherein the 705 can develop the most economic arrangement of warehouses by optimizing space in the design of storage facilities and in assigning part locations.

4. Central parts billing. Central inventory control on the 705 will make possible the use of this equipment in invoicing operations. Studies of this application have not been completed, and may result in a decision not to centralize this accounting function. There is no question as to the capacity or ability of such equipment to handle this work, but careful judgement must always be exercised in selecting proper applications. Other considerations could quite possibly prompt adverse decision.

5. Terminal buys. As a part approaches the state of obsolescence, it becomes necessary at some time to manufacture the final lot before scrapping the tools. The two critical questions are "when" and "how many"? It is felt that quite possibly a mathematical approach can be made utilizing historical sales data, which will at least bring a greater amount of data into the consideration — an amount not feasible in human calculations. The objective is, of course, to scrap the tools as soon as they are used for the last time (which implies a knowledge of when is the last time) and to have exactly the correct number of parts available to meet demand. An operations research study is now being made to determine if use of the 705 for this purpose is warranted.

And now, in conclusion, let's examine the value of the 705 as a control center for the national distribution of parts. We expected, and we are realizing improvement in three ways. First, it has reduced the human effort; second, it has reduced inventories; and third, it has improved the service we are able to give our customers. Each of these is a valuable improvement. The reductions in human effort and inventories provide ample tangible savings to pay for the equipment. The improved service means fewer back-orders, increased sales, and satisfied customers.

To Order Paper No. 39T . . . on which this article is based, see p. 6.

Plant Site Selection Demands Careful Study

Based on report by secretary

CHARLES W. CROUCH

General Motors Corp.

FINAL selection of a site for a proposed plant should be based upon:

1. **Size of site.** Provisions for parking lots, future plant expansion, purchase of ample land, considering future increases in real estate costs all make this a very important factor.

2. **Transportation.** Railroad facilities are a basic requirement, since trucking can be provided almost anywhere.

3. **Utilities.** Storm and sanitary sewers, water supply, gas, and electricity are all necessary. Deep wells may be needed for water supply in rural areas but are sometimes inadequate for heavy industry. It may be necessary to negotiate with local governments for construction of water supply lines, storm drains, and such. In one case, a local authority promised to build water lines; however, a local ordinance was required for such con-

struction five miles beyond the city limits. It is always wise to check statements by local authorities.

4. **Highways.** Good transportation facilities for trucking, employees' use, and for advertising are necessary. New plant locations near main turnpikes have considerable value as an advertising medium; however, state and federal laws restricting location of signs near highways must be checked.

5. **Topography of site.** A level or nearly level site with good surface drainage is the ideal. When other factors dictate the use of sloping land, the cost of grading and other earthwork should be included in the site cost. A check on soil conditions, with borings taken if possible before purchasing, is a wise precaution, since underground troubles sometimes develop.

6. **Zoning.** In most areas in this country, zoning restrictions affecting industry have developed and are frequently being changed. Ordinances covering industrial zones often allow residential building, but the reverse is not true, or frontages are zoned commercial with industry kept to the rear. Rezoning often creates difficulties and delays.

7. **Taxes.** This everpresent problem has a bearing in each case but may be of minor importance. Check details of local offers of free real estate taxes for five or ten years, since other property taxes may be high Some cities grant concessions in taxes on an existing plant for sale to encourage an influx of industry.

8. **Right of Possession.** Sometimes site or property under consideration involves buildings or land being rented or leased. Legal suits have developed when lessees refused to vacate the property, so delays tie up the transaction. Check to determine the legal rights of possession of all parties.

9. **Title Problems.** The title search to determine legal ownership and to expose any liens is of elementary importance. All manner of easements for use of land, possession by minors, and local political involvements are discovered. Ownership of land by people under twenty-one caused delays in one case, while discovery of an unsual easement prohibiting temporary access to adjacent land for maintenance of building purchased had to be cleared up in another case.

Serving on the panel which developed the information in this article, in addition to the panel secretary, were: **Hugh Arnold, William O. Margrove, George R. Elges,** and **Jack C. Berry,** all of General Motors Corp.

(This article is based on a secretary's report of a production panel entitled "Shall We Build a New Plant or Remodel?" This report — along with 8 other secretaries' reports on various production subjects — is available in multilith form as SP-326. See order blank on p. 6.)

Static Electricity Potential Jet Hazard

Based on paper by

G. T. COKER and H. R. HEIPLE
Shell Oil Co.

(Presented before SAE Metropolitan Section)

STATIC electric generation in turbine fuel has become a serious problem. Higher fueling rates, and the differences in flammability characteristics between aviation gasoline and jet fuel are the two factors contributing to this situation. Under normal temperature conditions vapors in contact with aviation gasoline are generally too rich to support combustion, while vapors in contact with jet fuels will support combustion over a wide temperature range.

Laboratory experiments have shown chemically pure hydrocarbons to be electrically inert, hence the electrical effect in fuels is related to the presence of trace materials, which are thought to form ions by dissociation — positively and negatively charged particles.

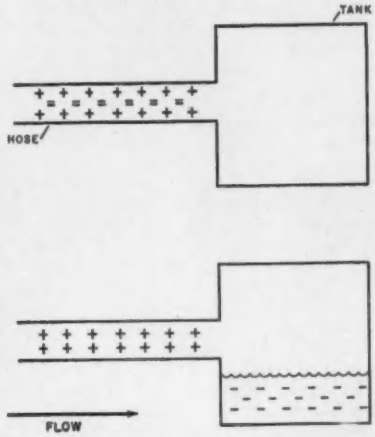

Fig. 1 — Mechanism of static electric generation, showing the distribution of positive and negative ions. When the fuel is in motion a current of a few microamperes is generated, and if allowed to accumulate will acquire a voltage sufficient to produce sparks.

Mechanism of Generation

The mechanism of static generation in flowing streams is illustrated in Fig. 1. The ions have different affinities for the pipe wall or other material in contact with the hydrocarbons. It is assumed here that the positive ions absorb on the surface in preference to the negative ions. The reverse is equally plausible and the sign of the absorbed charge appears to depend only on some undefined fuel property. The layer of positive charges on the wall will attract negative ions. Consequently, there is a fixed layer of positive charges on the wall and a mobile layer of negative charges close to the wall. These two layers are known as the electric double layer and may be regarded as resembling the plates of a charged condenser.

When the liquid is in motion this mobile layer will tend to be stripped from the boundary or double layer and the flowing liquid will contain an excess of negative ions. During such motion a current of a few microamperes is generated and, if permitted to accumulate, a voltage sufficient to produce sparks could be obtained.

Certain conditions can increase electrostatic hazards. The presence of additive materials such as corrosion inhibitors, lubricating oils, and contaminates may make the fuel more active electrically by increasing the charging tendency without having a pronounced effect on conductivity. Low temperatures can reduce fuel conductivity and the conductivity of rubber hoses during refueling. And the presence of free water generally represents an extremely hazardous condition.

Possible Solutions

If further investigation proves the reality and extent of the hazard, two solutions to the problem have been proposed already. One of these calls for the use of a relaxation tank just before the fuel enters the airplane system. In theory it would be of such volume that the charges accumulated throughout the system would have a sufficient time to leak away. However, this might not solve the overall problem, since fuel supplied to the airplane even though it may contain no charge, might generate sufficient charge while passing through the tank inlet system once again to become a hazard.

A second approach would be to include antistatic additives with the fuel. The primary function of the additives is to increase the fuel conductivity without affecting the charging tendency. Thus, charges would leak away as fast as they were generated. But any new additive has a multitude of hurdles to jump. Its effect on turbine blade life, ability of filter/separators to function, and many other items must be considered. It should not affect the fuel adversely in any way throughout its distribution or consumption or both.

To Order Paper No. S151 ... on which this article is based, see p. 6.

Quality Control Is NOT Inspection

Based on paper by

ERROL J. LANCASTER

Ballistic Missiles Center, Air Materiel Command

(Presented before SAE Southern California Section)

QUALITY control could contribute much to improve design reliability. Most engineering groups, for example, have a procedure for reviewing all specifications and drawings. In both method and intent, this procedure is similar to inspection rather than quality control. Inspection is concerned with detection of deficiencies, while quality control seeks to prevent basic cause and has four elements — preplanning, measuring or inspection, analysis of the basic cause of deficiencies, and finally, correction of that cause.

Correcting the basic cause does not mean changing the drawings or specifications. It means finding out why the basic error was made. For instance: Do we need more training in certain areas? Are procedures and guides incorrect or ambiguous? Is supervision lax? Unless an attempt is made to eliminate basic cause, we cannot hope to reduce the number of errors and the probability is high that some will slip past the reviewing personnel.

Reliability programs will become truly effective only when we learn to concentrate on prevention in both design and quality control.

To Order Paper No. S171 ... on which this article is based, see p. 6.

How to Compound Silicones for Seals

Based on paper by

H. E. TODD and J. F. MIAZGA

Pratt & Whitney Aircraft Division, UAC

IT is the properties involved in the confinement and compression of silicone rubber static seals that are important, rather than the conventional properties of tensile strength and elongation, which are little used.

Because higher temperatures accompany increased powerplant requirements, the compressive properties of these seals need to be measured at realistic service temperatures to determine their true capabilities. Such tests have been conducted and certain generalizations derived therefrom to guide the selection of silicone rubber compounds for specific applications. These are:

1. Compounds of 60–70 durometer hardness provide the lowest compression set, but harder compounds are superior for high compressive stress requirements.
2. Compounds containing precipitated silica as a filler show generally superior resistance to open heat exposure and have moderately high compressive stress characteristics. They are also superior in compression set properties below 400 F. Above this temperature compression set increases rapidly, and those compounds are subject to reversion under conditions of confinement.
3. Compounds with fumed silica fillers are somewhat superior in original physical properties, in resistance to confinement at high temperatures, and in compression set at temperatures above 400 F. Resistance to heat exposure is intermediate and compressive stress properties are rather low.
4. Diatomaceous silica fillers, when used alone, furnish only moderate reinforcement to silicone rubber compounds. When used in conjunction with higher reinforcing-type fillers, they contribute to high compressive stress properties at low and moderately high temperatures, and do not appear to affect compression set properties adversely.
5. Ditertiary butyl peroxide is the best of the catalysts for low compression set and may contribute slightly to improved heat resistance. In other respects none of the catalysts shows distinct advantages, except perhaps with respect to processing and curing of compounds.
6. The pronounced effect of heat on virtually all the properties of silicone rubber compounds indicates a maximum temperature limitation of 500 F for their successful use in seal applications.

To Order Paper No. 50V ... on which this article is based, see p. 6.

Briefs of SAE PAPERS

Continued from page 6

establishing cleanliness level and full-scale tests with reliable filter/separator equipment is suggested.

Oil Drain Periods, H. JENNINGS. Paper No. S165. Paper is concerned with engine oil drain periods as means of maintaining satisfactory oil film on wearing surfaces of engine; various methods of maintaining this oil film are discussed with reference to fleet operation involving trucks operating under particularly severe circumstances.

Oil Marketer Looks at Crankcase Oil-Drain Periods, J. W. LANE. Paper No. S166. Factors to consider such as effect of contaminants on engine condition and life, driving conditions imposed by traffic congestion, etc; for passenger cars and vehicles running under car conditions, 1000-mi drain period is recommended; for heavy duty fleet vehicles oil drain intervals can be established by study of operating conditions and maintenance practices in conjunction with used oil analysis.

Interpretation of Philosophy of Passenger Car Manufacturers' Recommendations for Changing Lubricating Oil, F. K. GLYNN. Paper No. S168. Data for years 1939, 1949 and 1959 are selected for detailed evaluation of manufacturers' recommendations and their varying approach to oil drain periods; charts summarize final findings of study covering 12 makes of passenger cars; it is concluded that four of car manufacturers are realistic in their recommendations, and that 5 manufacturers are proceeding in right direction.

GROUND VEHICLES

Design Features of European Trucks, J. ALDEN. Paper No. 31R. Features of vehicles from Norway, Sweden, Western Germany, Italy, Spain, Great Britain and France; composition of European market; European basic vehicle layout; engine types used; greater use of diesels of 4-cyl direct injection types; basic chassis-frame design; use of leaf spring suspension for vehicles of 6000 lb GVW and other types; trend in wheel and tire development towards smaller diameters; front and rear axles; transmissions and brakes.

Dynamic Structural Test Procedure, G. KLAASEN. Paper No. 34R. Equipment at Chrysler Corp. to determine car structural dynamics at shake frequencies consists of vector force elec-

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Continued from p. 106

tromagnetic vibrators and electronic power supplies, velocity type vibration transducers and indicating meter, 2-channel direct writing oscillograph with ampliers, force transducers and indicating meter, and IBM 650 computer; described standard procedure makes it possible accurately to predict shake behavior of car on most any road.

New Dimension in Motoring, E. J. HARDIG, M. P. deBLUMENTHAL. Paper No. 33T. Approach taken by Studebaker-Packard Corp. in developing Lark family of four body styles with choice of color, power, transmissions, and accessory option, fitting into smaller package without sacrificing any of refinements associated with American cars; details and illustrations of components, seats and interior.

Can We Measure Riding Comfort Electronically? A. C. BODEAU. Paper No. 34T. Riding comfort defined as subjective reaction of observer to seat induced motions; riding comfort measurements classified in two groups, analytical and comparative; instrumentation and techniques to economically process and analyze statistically significant quantities of data; oscillographic instrumentation used to determine pitching mode of truck tractor and its relation to motion of trailer; comparative measurement objectives.

Multi-Purpose Bodies—From Plush Pickups to Pint-Sized Pullmans, W. O. KOEHLER. Paper No. 35R. To demonstrate wide assortment of vehicles ranging from pickup trucks with passenger car styling and comfort buses with sleeping accommodations 22 typical examples of current multi-purpose bodies are illustrated and described; reference made to American and European popular models.

Fundamentals of Direct Acting Shock Absorber, G. W. JACKSON. Paper No. 37R. Details of elements and basic hydraulic circuit; control characteristic curves for various valvings; type of control to be applied depends on structural characteristics of vehicle and philosophy of manufacturer; reference made to designs produced by Delco Products and example of restricted type of valve coding; development of integral mounts; problem of controlling aeration of oil and methods used to reduce it; performance of nylon cell unit vs other types.

Influence of Tire Shape on Ride and Handling, W. H. HULSWIT. Paper No. 37T. Four different pneumatic tire shapes or cross sections are considered; circular arc, low profile, extremely wide rim, and restrained or belted tire; features and elements of performance such as tread mileage, skid and traction properties, stability, noise, ride, power consumption, and carcass durability; in general, characteristics of belted tires seem to be more advantageous for truck use than for passenger car use.

Exhaust Systems, Fundamentals and Design Considerations, L. E. MULLER, Paper No. 38R. Details of sound equipment used at Buick Motor Div., including sound analyzer and recorder, to break down exhaust noise into its spectrum and determine frequencies of which it is composed; design factors to consider such as chamber location;

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Briefs of SAE PAPERS

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resonators and use of multiple chambers and louvers; selection of type of cross section for muffler; method of testing material for cold corrosion; requirements for connections.

Cold Acoustical Tests of Mufflers, R. R. REGELBRUGGE. Paper No. 38S. Merits of method by which sound waves of known frequency and magnitude are sent into silencing circuit at room temperature, to determine effect of circuit on characteristics of input wave; by analysis of silencer sound output as compared to known input, it is possible to determine muffler attenuation for input and test conditions; example of how cold testing can be of value in studying silencing characteristics of simple circuits and in predicting efficiency.

Muffler Location is Important, T. A. DANNER. Paper No. 38T. Role of acoustical tuning of muffler and tuning of pipes and location of muffler in respect to other exhaust system components for efficient use of muffler volume available; tests made with three mufflers first of which was designed for use in forward position, second for center location and third one for rear location installation; curves showing effect of location on attenuation characteristics; for efficient utilization muffler must be designed for specific use.

Muffler Corrosion—Its Cause and Control, R. A. HEATH. Paper No. 38U. Notes on development of muffler design and materials used such as coated steels, hot dipped zinc material for mufflers, and aluminized steel; materials tests and temperature tests on single and dual exhaust systems; reference made to various designs; use of condensate drainage; it is believed that acid condensate and its attack on mufflers is controlled to acceptable limit by use of hot dipped zinc and aluminized steel and by design; future research program.

Factors Affecting Engine Performance, D. L. LENANE. Paper No. S144. Methods for increasing engine performance; power may be raised by improving volumetric efficiency through better manifolds and fuel metering equipment or by use of supercharger; power and fuel economy can be improved by using fuel injection if fuel distribution is poor with carburetor, and by raising compression ratio; fuels for increasing engine power; relationship between compression ratio and

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Briefs of SAE PAPERS

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octane number requirement for two V-8 engines.

Developments in Immediate and Future Bus Transportation—Designing for Passenger Appeal, G. E. MINTZ. Paper No. S153. Approach taken by Mack Trucks, Inc., in designing city bus with better passenger appeal; requests from bus owners and operators, from passenger surveys, etc, were collected and analyzed; suggestions made with regard to future design concerning exterior appearance, doors, bus width, floor height, and interior design; air conditioning, heating, and noise reduction; driver satisfaction factors.

Basic Design of Turbochargers for Diesel Engines, H. EGLI. Paper No. S157. Basic requirements and design characteristics with emphasis on compressor and turbine; aerodynamic and thermodynamic performance criteria with regard to compressor density ratio, compressor efficiency, overall turbocharger efficiency and impeller tip speed; four types of turbomachines used for turbochargers, classified according to flow pattern in meridional plane; radial compressors; factors which determine size of turbocharger; rotor configuration.

Service and Maintenance of Turbochargers and Turbocharged Engines, J. A. HARDY. Paper No. S159. Factors that affect service life of turbocharger and turbocharged engines are considered and characteristics of turbocharged engine that lead to service problems; service and maintenance work on turbochargers is divided into following categories: cleaning, bearing clearance check, and replacement of worn or damaged parts; recommendations and list of do's and don'ts.

Automatic Transmission Testing, H. H. KEHRL, M. R. MARSH, R. A. GALLANT. Paper No. 30R. Transmission laboratory work discussed with particular reference to Chevrolet Powerglide and Turboglide transmissions; methods of components testing such as evaluation of friction element capacities, both static and dynamic, and equipment used; testing of thrust water, static and dynamic overrunning clutch, and converter; complete transmission testing emphasizing abuse test and programmed durability test.

Electronic Testing of Body Mechanisms, A. S. BASSETTE. Paper No. 34S. Testing of all body functions which are not primarily structural such as locks, rear view mirrors, and sound qualities of body; examples of type of problem and equipment employed at Fisher Body Div. Proving Ground, relating to rear view mirror studies, using recording oscillograph; use of X-Y plotter for shake studies; application of strain gages in study of loads in body mounting points and in determining of loads in hood latches; setup for sound analysis.

Ride and Handling—Effect of Tire Cords, J. J. ROBSON, R. S. LEE. Paper No. 37S. To determine if laboratory evaluation can provide clues to isolate ride and handling effect of two types of cords (nylon and viscose), Firestone Tire & Rubber Co. used two approaches: laboratory evaluation comparing deflection characteristics enveloping capacity and dynamic impact, and "trial by jury" method with group of ride testing experts and laymen; results show clues can be found

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Briefs of SAE PAPERS

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in laboratory; differences between nylon and viscose cords are small.

Practical Approaches to Cold Weather Testing, C. C. RUNYON. Preprint No. 30S. Problem of outdoor testing for performance of engines, heaters, defrosters, fuel induction systems and other automotive components; how these problems are overcome by cold room testing, and practical procedures for reproducing natural problems in laboratories; precautions taken and specialized equipment used at Ford's cold room laboratories.

MATERIALS

Quality Determination of Automotive Front Suspension Torsion Bar Springs Through Fatigue Testing, R. F. GRISWOLD. Paper No. 32S. Application of "fatigue-quality" concept at Chrysler Corp. by use of exhaustive fatigue test programs as vital adjunct to determination of quality for front suspension torsion bar springs; specimen fatigue tests as part of program carried out in accordance with statistical methods developed by Applied Mathematics Panel; results of tests made on two small, experimental heats of steel CM 3204 and 3207; other examples.

New Automotive Primers, J. D. SKANDALARIS. Paper No. 36R. Review of development of vehicle binders with special reference to epoxy resins as new materials; functions of primers are to provide maximum protection for metal surface, adhesive base for color coat, and smooth surface on which to apply color coat; testing techniques at Organic Materials Laboratory of Chrysler Corp., to evaluate primers with regard to following characteristics: workability, impact, humidity, salt spray resistance, and water immersion.

Acrylic Lacquer, W. E. MITCHELL. Paper No. 36S. Summary of program in developing new painting material at Fisher Body Div. of General Motors Corp.; acrylic lacquer is poly-methylmethacrylate, outstanding feature of which is its gloss retention; how problems involved in painting procedure were solved by using circulating paint spray system, and recirculating paint spray system with auxiliary circulation to spray gun; typical spray station and spray gun connection components.

Super Enamels, W. H. SUTER. Pa-

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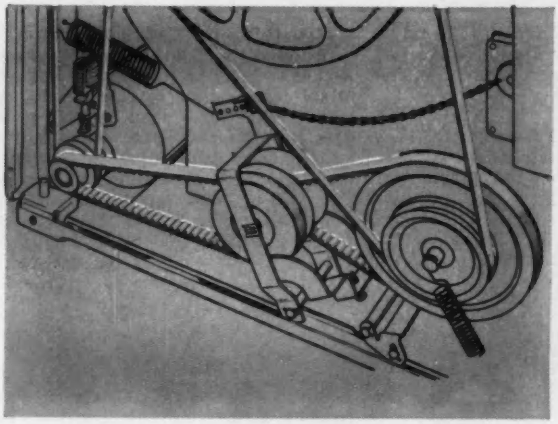
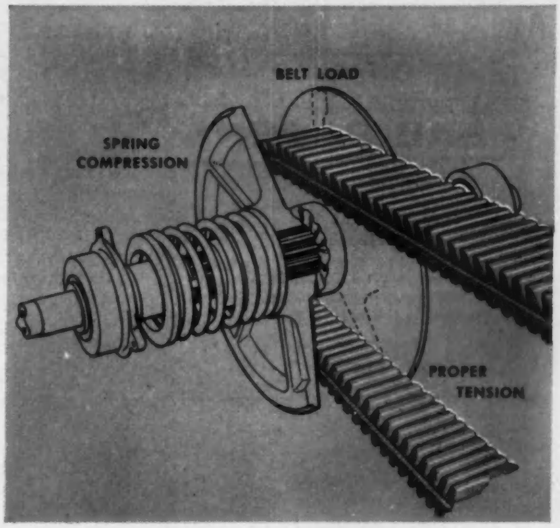
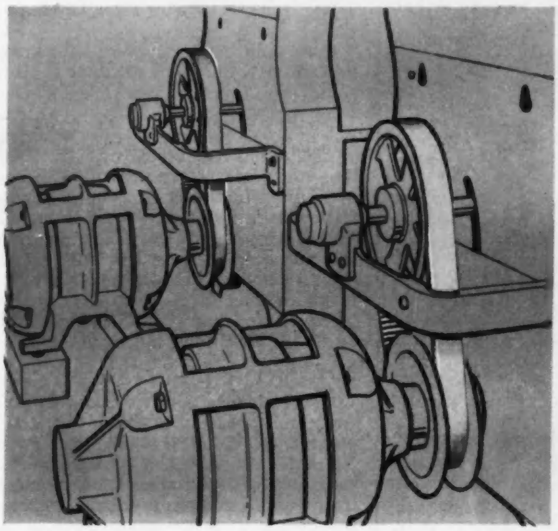


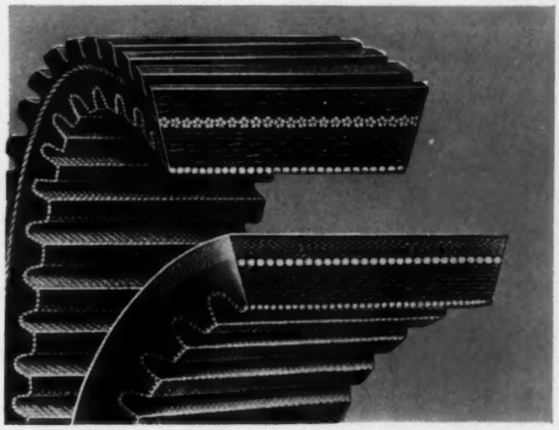
Instead of shifting gears, which have been eliminated in this combination washer-dryer, RCA Whirlpool employed this smooth-performing Dayton equipped variable speed drive to change drum speed from 45 r.p.m. during the tumble cycles to 200 r.p.m. during the spin cycles.



Engineered for maximum crosswise rigidity, Dayton Cog-Belts withstand heavy shock and impulse loads without squashing or deforming. This feature, plus surer gripping molded raw edges, gives double assurance of precise speed control under any operating condition.



For years, textile spinning frames were driven by overhead flat belt drives . . . then interchangeable multiple V-Belt drives. Efficient Dayton Variable Speed Drives, capable of being adjusted within one r.p.m. of optimum speed for unvarying quality and maximum production, now provide the most up-to-date power transmission method.



The exclusive Cog design gives Dayton Variable Speed V-Belts maximum lengthwise flexibility needed for bending around sub-standard diameter sheaves without strain or excessive heat build-up. This stronger, lighter-weight construction operates at speeds up to 2000 r.p.m. with a minimum of centrifugal force or internal stress.

® Registered

Dayton Rubber

WORLD'S LARGEST MANUFACTURER OF V-BELTS

Industrial Sales Engineers in Atlanta, Chicago, Cleveland, Dallas, Dayton, Minneapolis, Moline, New York, San Francisco and St. Louis

Briefs of SAE PAPERS

Continued

per No. 36T. Ford's program in development of new enamel which is formulated with cocoanut fatty acids, which is non-drying alkyd and heavily fortified with amino resins; performance features and problems involved in introducing Super Enamels.

Metallizing Applications for Wear Resistance and Salvaging, K. B. SMITH. Paper No. 40S. Some of metallizing applications used by auto makers and their suppliers for both plant equipment maintenance as well as production and production salvage; particular reference made to every day machinery repair problems solved by metallizing.

Metallizing for Corrosion Protection in Automotive Field, S. TOUR. Paper No. 40T. Review of various sprayed metal coating processes and their possible applications to automotive products; systems developed to meet different corrosive conditions comprise pure metallic zinc or aluminum coatings applied by metallizing; details and examples of applications of four systems for protection of steel at elevated temperatures; System 120 for use up to 900 F and Process 11, 33 and 45 for higher temperatures.

PRODUCTION

Progress in Space Age Materials Fabrication, L. E. LAUX, C. S. HILL. Paper No. 43S. Experiences gained at Martin Co. in developing fabrication techniques for high strength heat resistant materials for military weapons systems; application of Marform process to forming problems presented by high strength steels; techniques employed in producing cylindrical type pressure vessels; honeycomb structures, fabrication of honeycomb core, machining and forming, etc.

Cost Improvement Story at Arma, F. J. MORGAN. Paper No. 44S. How American Bosch Arma Corp.'s Cost Improvement Program for reducing costs of operations, provides means of participation for executive, administrative, and supervisory personnel in cost proposals; handling of proposals submitted and cost analysis by Industrial Engineering Dept.; examples of proposals accepted in regard to checking of color coding of components, changing from anodize to alodine 1200 process in machine shop's metal preparation section, etc; savings obtained.

Requirements Guidance and Control Systems Impose on Manufacturing Departments, C. McWILLIAMS. Paper No. 45R. Steps taken by Eclipse Pioneer Div. of Bendix Aviation in meeting manufacturing problems imposed by specific requirements of missile applications; methods and concepts used relating to planning, scheduling and organization of cost reduction programs; problem of precision, calibration and machining accuracies is shown by example of air bearing gyro used on ballistic missiles; final calibration of dead reckoning computer.

Improved Reliability Through Total Team Effort, R. E. KIBELE. Paper No. 46R. Approach taken by North American Aviation Inc., to produce dependable design of airframe weapon system or missile which must include provisions for performance, safety, simplicity of operation, producibility, and maintainability, all within appropriate cost structure; role of reliability analysis engineer; one of most difficult phases of achieving improved reliabil-

Continued

Lucky Stores, Inc., relies heavily upon Diesel-engined White-Freightliner COE Tractors for dependable transportation of goods to its 110 supermarkets. All of Lucky's Freightliners are equipped with Fuller R-96 ROADRANGER Transmissions.

Geared by FULLER . . .

Lucky STORES eliminates transmission maintenance problems

"A truck failure during a run in the desert heat would mean a loss of thousands of dollars worth of fresh produce," says Joseph F. Schaeffer, Vehicle Maintenance Superintendent for Lucky Stores, Inc., San Leandro, California.

Because the huge supermarket chain trucks more than $100 million worth of foodstuffs a year to its 110 modern stores, Lucky has instituted a comprehensive preventive maintenance program and has been careful to purchase efficient, reliable equipment.

Backbone of the Lucky Stores fleet are Diesel-powered White-Freightliner COE Tractors, all of which feature 10-speed, semi-automatic Fuller R-96 RoadRanger® Transmissions. Experience with these transmissions, together with Fuller 5-A-65 Transmissions in Lucky's White WB-28T Tractors, has been exceptionally satisfactory.

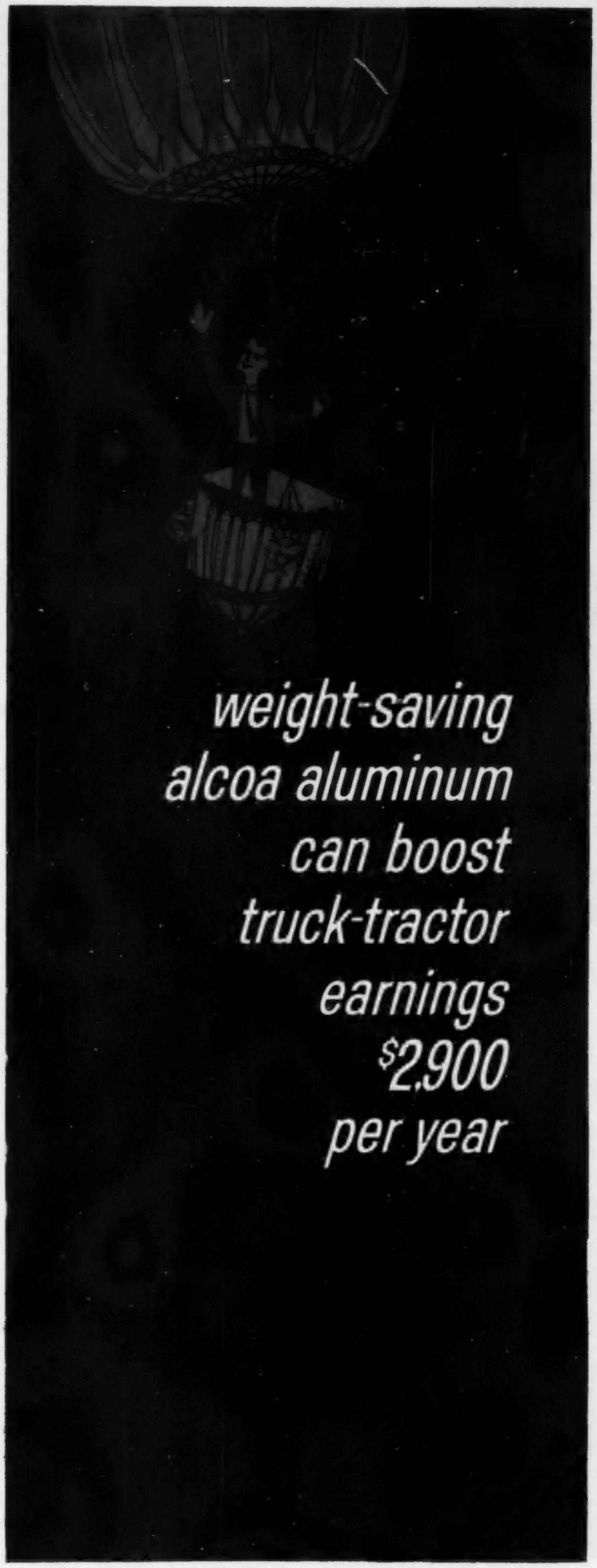
Mr. Schaeffer says, "We haven't had a main box down in the last five years. We're going to standardize on the RoadRanger for diesel and gasoline tractors in the future. Our drivers like them and we are having no maintenance problems whatsoever."

Ask your truck or equipment dealer about the Fuller Transmission designed to put more profit into *your* particular operation.

FULLER — TRANSMISSION DIVISION —
MANUFACTURING COMPANY
KALAMAZOO, MICHIGAN
Subsidiary EATON Manufacturing Company

Unit Drop Forge Div., Milwaukee 1, Wis. • Shuler Axle Co., Louisville, Ky. (Subsidiary) • Sales & Service, All Products, West. Dist. Branch, Oakland 6, Cal. and Southwest Dist. Office, Tulsa 3, Okla.,
Automotive Products Company, Ltd., Brock House, Langham Street, London W.1, England, European Representative


1959



The fleet operator today is willing to pay a premium for every pound of dead weight trimmed from his equipment. The reason—narrowing profit margins and confining legal weight limits. Every pound of dead weight shed makes way for an extra pound of payload worth $1 a year—or even more—in extra revenue for the operator.

2,896 Lb—Total Weight Savings With Aluminum. Alcoa, through research and close work with truck builders, has made it possible to give you the means to eliminate up to 2,896 lb of dead weight by designing with aluminum. The premium paid for an aluminum unit is returned to the operator in the first year of service; after that, it's all extra profit. Here is where these weight savings can be made:

2,025 Lb in Chassis Applications. Tandem rear axle components—axle housing, differential carrier castings, brake spiders and shoes and wheel hubs—save 570 lb in aluminum, compared to steel. Ten Alcoa® Aluminum Forged Disc Wheels each weigh 36 lb less than their steel counterparts, and savings of 280 lb on spring hangers and tandem axle suspension bring the total weight reduction to 1,210 lb.

Use of extruded and fabricated aluminum parts for structural members, fuel and air tanks and the front bumper can save an additional 815 lb. The extrusion process, by putting the metal exactly where it is needed for strength, provides the most efficient frame rails obtainable today.

541 Lb in Engine and Accessories. In an engine of approximately 500 cu in., aluminum cuts weight by 250 lb in the cylinder block and crankcase alone. Other reductions in the cylinder head, oil pan, timing gear cover, intake manifold and flywheel housing add up to 393 lb. Weight savings reach 541 lb through other reductions in the clutch housing, transmission case and cover, and auxiliary transmission case and cover.

330 Lb in Cab Components. There are 18 major components in cab design where aluminum cuts weight. Exterior and interior door panels and rear panels, roof, cowl, dash seat box, battery box and rear floor assembly all weigh 50 per cent less in aluminum. Weight saving for the radiator shell assembly is a whopping 47 lb. An aluminum hood assembly weighs only 31 lb, compared to 69 lb for its steel counterpart. Other important reductions occur in floor board, toe board, toolbox pan, radiator core, running-board assemblies and miscellaneous reinforcements. In all, they add up to a reduction of 330 lb.

Let Alcoa Help. Alcoa researchers have over a half century of experience and have developed over 90 per cent of all aluminum alloys. They have at their disposal the largest and most modern facilities in the industry. All this is available to help you design maximum profit through minimum weight into America's trucks. Let us work with you on the development of aluminum applications for high-performance automotive equipment. Write Aluminum Company of America, Development Division, 1785-F Alcoa Building, Pittsburgh 19, Pa.

ALCOA ALUMINUM GIVES EVERY CAR AND TRUCK MORE GLEAM AND GO

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

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Your Guide to the Best in Aluminum Value

Briefs of SAE PAPERS

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ity exists in customer relations field; recommendations made.

Production of Reliable Electronics in Space Age. Consistency — Production Man's Key to Reliability, J. M. WUERTH. Paper No. 46S. Specific reliability tools developed for designing equipment at Autonetics Div. of North American Aviation, contains techniques for specifying quantitative reliability, predicting reliability based on component and circuit data, testing, classifying, and selecting components, etc; importance of consistent manufacturing processes; requirement for process control discussed in terms of soldering certification program.

Machining of Ultra Strength Alloys, J. MARANCHIK, Jr., J. V. GOULD, P. R. ARZT. Paper No. 43R. Results of machinability studies performed by Metcut Research Associates Inc. under Curtiss-Wright Corp. contract, on high strength thermal resistant alloys as follows: martensitic low alloy steels, hot work die steels, and precipitation hardening stainless and austenitic stainless steels; machining information presented in form of tool life curves, etc; summaries of machining data relating to turning tests, milling, drilling, and tapping tests.

Electronic Data Processing . . . From Design to Production Control, J. J. Di-CICCO. Paper No. 39S. Equipment used at Chrysler Corp. consisting of computer with two tape inputs, four tape and punched card output, tape data selector and six tape stands; application to planning and control of new model pre-production programs, including processing and distribution of detailed production and material specifications, selection and installation of changes to improve product and to facilitate production of cars and trucks.

Control of National Parts Distribution by Electronic Computer, B. ZACHARIAS. Paper No. 39T. Office methods improvements at Chevrolet Motor Div., made possible through installation of IBM 705 computer to control phases of producing, processing, warehousing and distributing over 50,000 different parts; sales activity involves 42 warehouses selling to dealers, 13 warehouses handling slower moving items, and four major supply depots; details of control center system to handle national distribution.

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Briefs of SAE PAPERS

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Use of Market and Customer Order Data in Manufacturing Scheduling, J. E. ZIMMERMAN. Paper No. 39U. System used at Ford Motor Co. to establish Mercury manufacturing scheduling for four assembly plants for each 6 mo period; system incorporates four computer programs, with fifth under development; details of programs to provide right parts to line in order to build vehicles of body mix, option, and trim combination equal to incoming orders; fifth program involves analysis of vendor performance to shipment release, and in-plant parts control.

Operations Planning at Saginaw Steering Gear, E. W. CUMMINGS. Paper No. 41R. Principles applied at General Motors in planning of new product at most economical cost; close working relationship of product and manufacturing engineers is major step in program; examples relating to savings made possible in production of propeller shaft spider bearings by cold forming part instead of removing metal by conventional machinery; automatic "lectron" gun painting of power steering pumps, etc.

Design Factors Affecting Machine Efficiency, K. O. TECH. Paper No. 41S. In selecting machine tools or in setting machine tool specifications there are number of considerations that are treated superficially which contribute to ultimate efficiency, economy and troublefree operation; these overlooked factors relate to flexibility, accessibility, tool changing, electrical arrangement, work height and identification; examples and recommendations are given.

Why and How Timken Company Built Automatic Bearing Plant, H. J. URBACH. Paper No. 41T. Concept applied at bearing plant at Bucyrus, Ohio, in production of automotive bearings in straight line production plant; example of management employee relationship and participation in program determining economics of carbide machining; in cooperative program with machine builders, machines were designed and tested before batteries of 11 lines were put into production; example of single spindle screw machine development.

Assuring Customer Satisfaction by Compact Car Organization, D. H. MONSON. Paper No. 42R. Discussion concerned with activity of Kenosha Plant of American Motors Corp.; merits of compactness of organization as related to customer satisfaction; examples of elimination of human element as means of improving quality and customer satisfaction; final inspection techniques and special checks performed on inspected cars chosen at random from each day's production; effect of production schedules on efficiency and quality.

Customer Acceptability Must Control Quality Standards, M. M. DEAN. Paper No. 42S. Approach of Ford Motor Co. in establishing quality standards geared to customer requirements; system devised to cover repairs made on cars upon customer request, called Dealer Repair Order Analysis Program; continuous field survey of dealer repairs to sample of cars produced each month by each assembly plant and sold by participating dealers; analysis of data obtained to evaluate overall production at each plant daily; reports and audits issued.

Shop Man's Operations Research, H. D. HALL. Paper No. 44R. Technique applied at General Motors contains elements of operations research and is extremely valuable in effecting important cost reductions; functions of process development staff, responsible for development of manufacturing processes which reduce costs and improve quality and planning team activity; seven steps in solution of given problem; procedure and results obtained.

These digests are provided by Engineering Index, which abstracts and classifies material from SAE and 1200 other technical magazines, society transactions, government bulletins, research reports, and the like, throughout the world.

ALSO AVAILABLE . . .

1959 SAE NATIONAL PRODUCTION MEETING . . . SP-326 consists of reports on 8 panels, as follows:

Economy of Correcting Assembly Troubles at the Source, reported by J. J. RYAN, secretary. Tells how to find and eliminate defective parts before they find their way into subassemblies and final assemblies as an effective way to fight rising costs.

Shall We Build a New Plant or Remodel?, reported by CHARLES W. CROUCH, secretary. Gives nine yardsticks to use when selecting a site for a proposed plant.

Can We Have Work Measurement for Preventive Maintenance?, reported by T. S. DALY, secretary. Preventive maintenance standards, where they can be used, undoubtedly prevent breakdowns and contribute to better conditioning of equipment and lower

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Briefs of SAE PAPERS

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costs. Tells how to devise a workable plan.

Scheduling: Relationship of Capital Expenditures and Inventory, reported by A. T. BLACKBURN, secretary. Discusses whether to invest in machines or inventory, how to justify new machine tools, and the scheduling of production with electronic data processing.

Cold Forming — Today and Tomorrow, reported by C. G. HASCALL, secretary. Substantial savings in material requirements, improved mechanical properties, and increased production rates are some of the advantages of cold forming. Pinpoints where cold extrusion of steel is practical, gives progress report on cold heading, and tells how to select materials for cold-formed parts.

How to Save Valuable Floor Space, reported by M. C. STEWART, secretary. Tells how to utilize roof areas in automotive assembly plant layout. Also discusses the use of power and free conveyors, vertical storage of process materials, and progressive dies and their relation to floor space.

How Can We Reduce Metal Finishing Cost?, reported by REX BREMER, secretary. Surveys precautions being taken to keep metal finishing down on bumpers, body stampings, front end sheet metal, and external ornamentation.

How to Save Time and Money on Press Tooling, reported by R. C. MEIER, secretary. Gives latest information on die automation, plastic and kirksite dies, cast-to-size dies, and electronic discharge machining of dies.

New Members Qualified

These applicants qualified for admission to the Society between April 10, 1959 and May 10, 1959. Grades of membership are: (M) Member, (A) Associate, (J) Junior.

Atlanta Section

Charles Merkle Jones (M), James J. Nally (A).

Baltimore Section

Roger F. Hansen (J).

British Columbia Section

Beverly Ian Davis (A) Alfred Edwin Mitchell (A).

Buffalo Section

John J. Hart (M), Peter J. Mutolo (A), Robert S. Wind (J).

Central Illinois Section

Walter David Cashman (J), Joseph P. Little, Jr. (M), Eugene Robert Martin (J), Cyril L. Rich, Jr. (J), Glen L. Rogers (A).

Chicago Section

John P. Behanna (J), Ervin F. Brinkman (A), Richard W. Hurckes (J), Emanuel M. Leon (A).

Cleveland Section

Frank W. Bowers (M), Arthur R. Breed (M), Richard H. Focke (M).

Colorado Group

B. C. Pittman (M), Robert E. Stetson (M).

Dayton Section

Donald J. Welter (J).

Detroit Section

Edward F. Austin (J), Ira James Barker (A), Earl L. Butler (A), Robert F. Childs (J), Frederick E. Detke (J), Ralph DiCicco (A), Glenn F. Doyle (M), Ray Fullagar (M), Neal H. Gammell (M), George P. Holman (M), William H. Houghton (A), James R. LeRoux (A), William Frederick Marshall (M), Thomas J. McKey (M), Elliott L. Myers (J), Norman A. Norris (M), Walter R. Opel (M), R. W. Pantalone (J), Gerald Garvey Peck (A), Roger Rafael Regelbrugge (J), S. T. Salvage (M), Dale W. Toms (M), Kenneth H. Woodrich (M), Elmer F. Zink (J), Fred N. Zinnbauer (M).

Hawaii Section

Robert H. Gutcher (A).

Indiana Section

George C. Brainard, Jr. (M), Walter G. Chew (M), James H. English (J), Walter J. Fisher (M), Tobi Goldoftas (M), Verle E. McCarty (M), Kenneth

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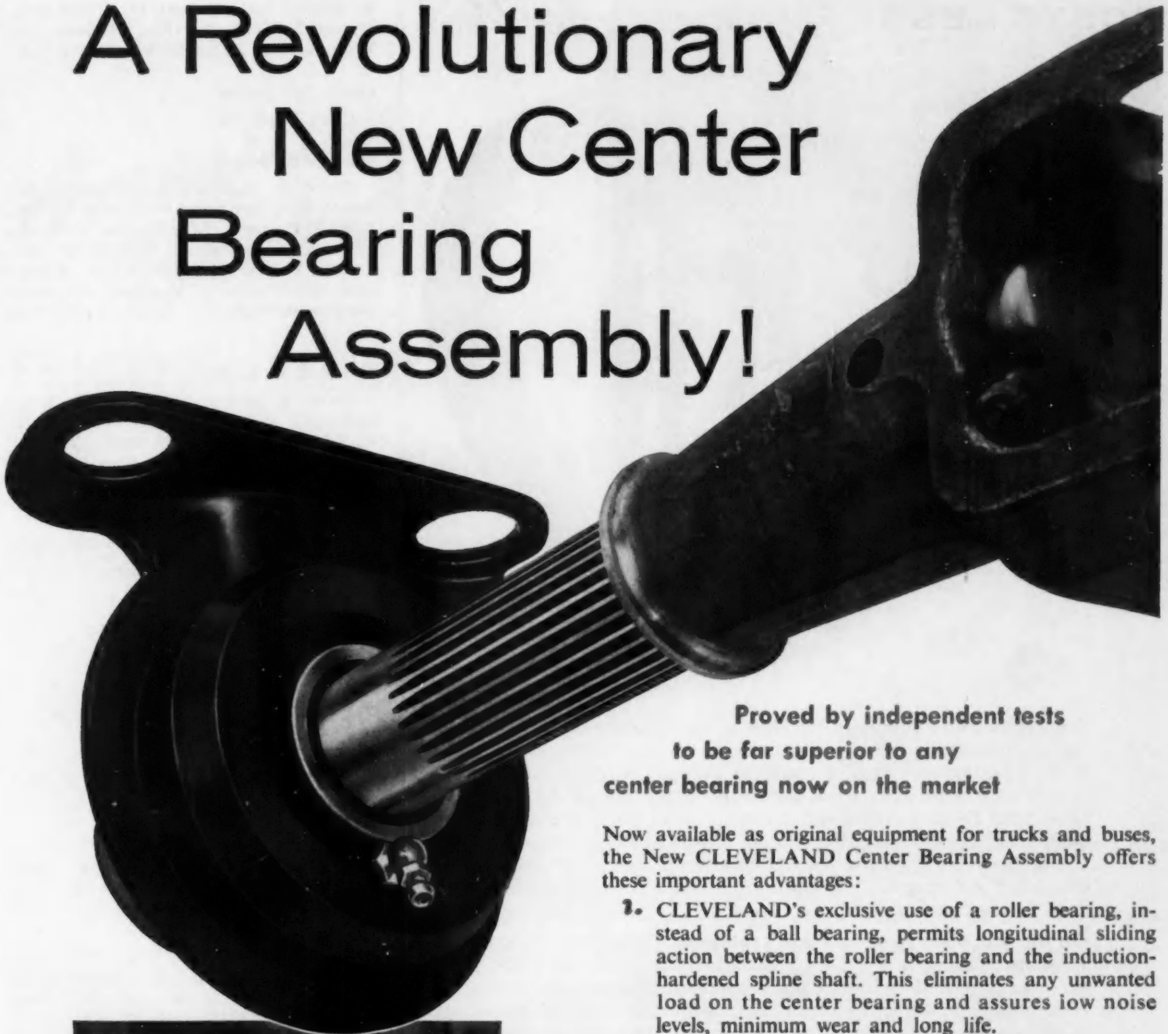
From CLEVELAND . . .

A Revolutionary New Center Bearing Assembly!



Proved by independent tests to be far superior to any center bearing now on the market

Now available as original equipment for trucks and buses, the New CLEVELAND Center Bearing Assembly offers these important advantages:

1. CLEVELAND's exclusive use of a roller bearing, instead of a ball bearing, permits longitudinal sliding action between the roller bearing and the induction-hardened spline shaft. This eliminates any unwanted load on the center bearing and assures low noise levels, minimum wear and long life.
2. CLEVELAND's new design absolutely eliminates center bearing "shudder". Also, it eliminates longitudinal misalignment problems between frame and bearing bracket.
3. CLEVELAND's Center Bearing Assembly embodies a conventional type grease fitting and lubrication channels to permit a complete flushout of any injurious road dirt.

Write for information on this remarkable new product. It's the answer to center bearing problems.

Since 1912
Cleveland Steel Products Corporation
Automotive Division
16025 Brookpark Road, Cleveland 11, Ohio

Universal Joints • Propeller Shafts
Power Take-Off Joints
Center Bearing Assemblies

New Members Qualified

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R. Moore (M), Robert D. Morss (M), Byron L. Stewart (M), Rodney Lee Wallace (J), Kenneth W. Young (M).

Kansas City Section

Cyril Pope (M).

Metropolitan Section

Clare E. Bacon (M), Stanley Jay Bruce (A), Hermann Bruns (M), (William F. Connell (M), Chester G. Davis (M), Daniel James Gallagher (A), James F. Harris (M), Alfred Monacelli (A), Harold R. Munhall (A), John George Reichel (J), Anthony W. Wilk (J).

Mid-Michigan Section

David F. Briggs (A), John B. Brennan (M), James D. Karn (M), Melvin H. Lill (M), Robert W. Podlesak (M), Clio F. A. Sanborn (J), Charles Raymond Wendt (M).

Milwaukee Section

Robert F. Blomquist (A), C. O. Groth (M), Charles Leo Salkowski (J).

Mohawk-Hudson Section

William Meaney (A).

Montreal Section

William Edward Armstrong (M).

New England Section

Donald E. Jenks (A), Lloyd H. McFadden, Jr. (A), Hector D. Petri (M).

Northern California Section

William Eugene Elder (M), Bernard S. Greenfelder (M), Floyd L. King (A).

Ontario Section

Norman H. Bell (A), Nicholas G. Grabb (M), N. D. Morgan (M), Fred Simon (M), Joseph Walsh (M).

Philadelphia Section

Leonard L. Berkan (M), Theodore F. Jackson (A).

Pittsburgh Section

Ashok M. Khilnani (J), Elias Malichky (J), Richard W. Twigg (M).

St. Louis Section

Jordan L. Heiman (M), Jack R. Snyder (M).

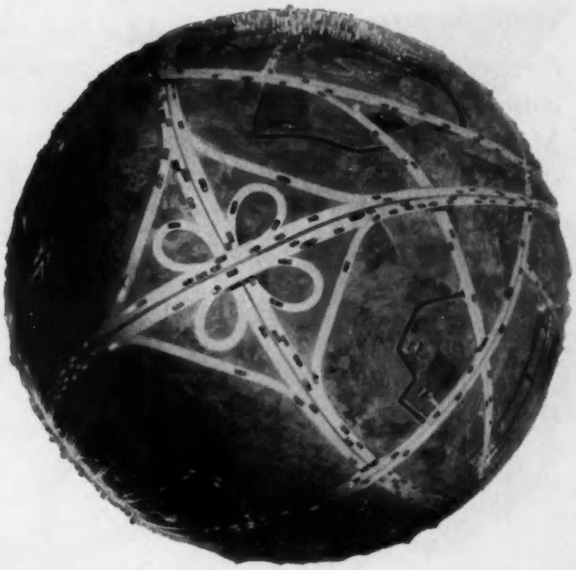
San Diego Section

James M. Purdon, Jr. (A).

Southern California Section

Philip H. Jones (M), Edward Kaz-

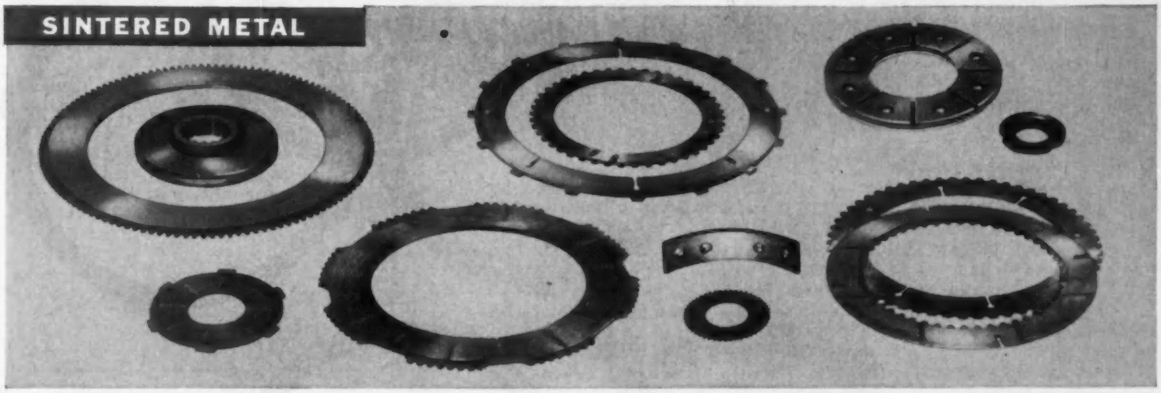
Continued

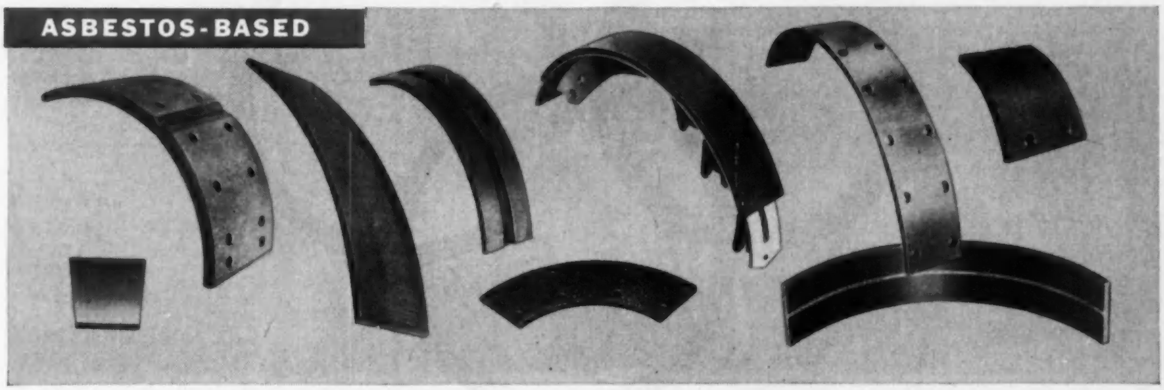


American Brakeblok®

FRICTION ELEMENTS

...for a world of stop and go





Brake Shoe

AMERICAN BRAKEBLOK DIVISION
P.O. BOX 21, BIRMINGHAM, MICHIGAN

New Members Qualified

Continued

marek (M), Owen J. McCaughey (M), George G. McKhann, Jr. (M), Donald F. Pepper (J), James N. Rauen (M).

Southern New England Section

Charles Wakefield Bishop (A), Harry J. Hermann, Jr. (A), Donald E. Manning (M).

Texas Gulf Coast Section

Clarence D. Anderson (M), William F. Goins (A).

Texas Section

Clarence Elmer Cain, Jr. (A), J. W. Mooney (A).

Twin City Section

Harry M. Hermanson (M), Dwayne Arthur Rule (M).

Western Michigan Section

Ernest Bader, Jr. (M).

Outside Section Territory

Maxwell Eaton, Sr. (M), L. W. Steege (M), Theodore N. Tunnecliffe (A).

Foreign

K. S. Ganpati (J), So. India; Graham F. J. Murray (M), England; R. Nagarajan (J), So. India; Henry M. Nazarian (A), Lebanon; K. S. Pillai (J), India; Gordon Reynard (M), England; S. G. van Hoogstraten (M), Holland.

Applications Received

The applications for membership received between April 10, 1959 and May 10, 1959 are listed below.

Alberta Group

Stanley E. Stauffer

Baltimore Section

Wm. M. Schell

British Columbia Section

Peter Hipp, Roy L. Larson, Rodney F. Leger.

Buffalo Section

Paul K. Beatenbough, H. Hugh Turner III.

Continued

Applications Received

Continued

Central Illinois Section

Richard Otto Lang, James A. MacLean, Gerald F. Molloy.

Chicago Section

William P. Hendershot, Wayne Allen Hennig, James George Kapoulas, Walter P. Kushmuk, Richard Muntjanoff, Richard K. Nelson, Frederick A. Simmons, Raymond E. Stokely, Einar Swedberg.

Cincinnati Section

John Baley.

Cleveland Section

William C. Douglas, Richard Charles Madigan, Fred L. Main, George H. Milleman, Carl F. Smon, Jr., James Paul Tompkins, A. C. Triplet.

Colorado Group

Donlad F. Joy.

Dayton Section

Wayne A. Karlgaard

Detroit Section

George W. Albrght, Mitchell C. Borowicz, Walter F. Brown, Roy L. Bailey, Richard G. Clearman, J. B. Dupuis, Thomas H. Elkins, Robert L. Filbert, Fremont Fisher, Alan D. Hayes, Herbert B. Hindin, William A. Houk, Hans E. Kutscher, Lynn A. Martin, Bernard G. Mazurek, Jr., Wilton D. Nelson, Vincent H. Oliver, Duane C. Perry, George Puia, Roy H. Robinson, Donald Leo Roskopf, Wilford J. Schaldenbrand, Francis C. Sering, Arthur F. Tarabusi, Dale A. Van Deven, Earl N. Verbridge, Maurice P. Whalley, Jr.

Hawaii Section

Joseph A. Murphy, Mahlon P. Woodward.

Indiana Section

Clarence A. Beverforden, Harold F. Brown, Arliss Johnson Gorby, Joe Brook Mechem, Robert H. Roth, Dean P. Stanley.

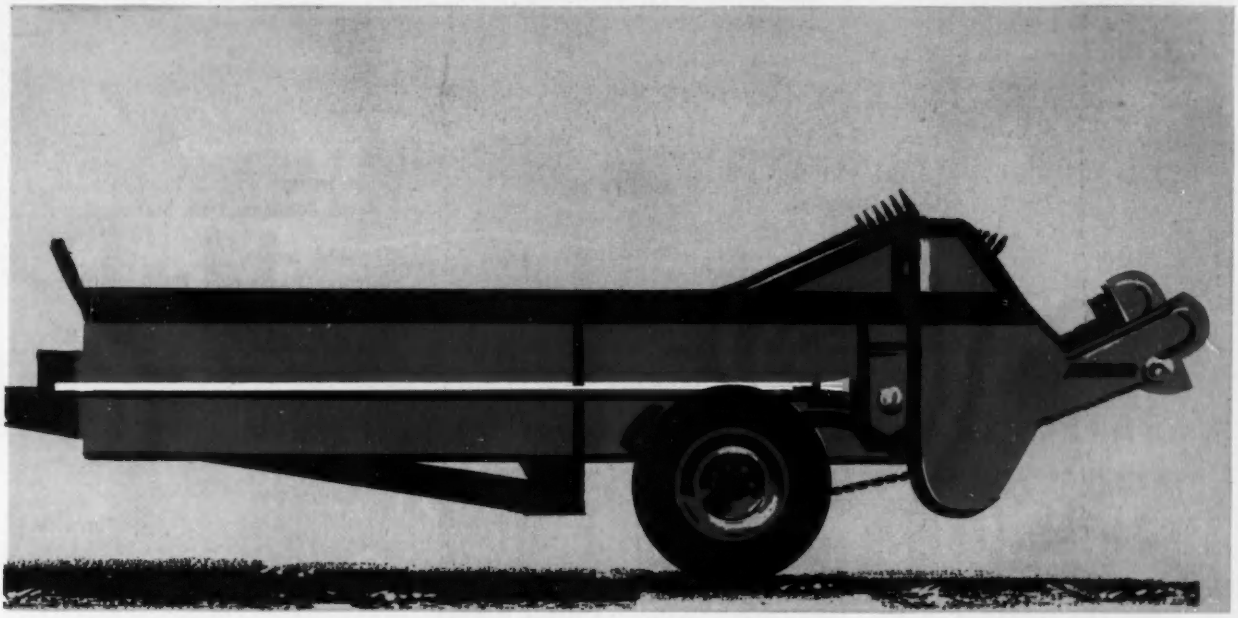
Kansas City Section

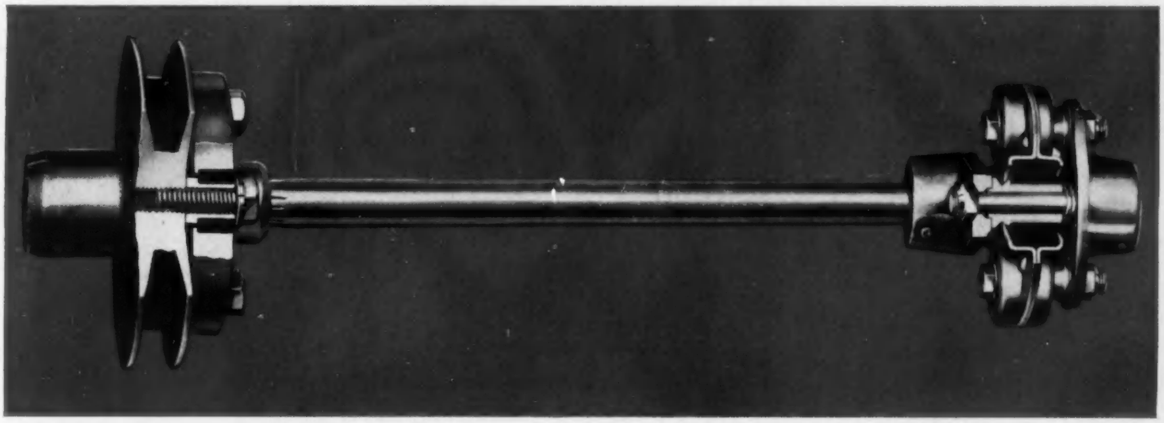
James E. Garrison.

Metropolitan Section

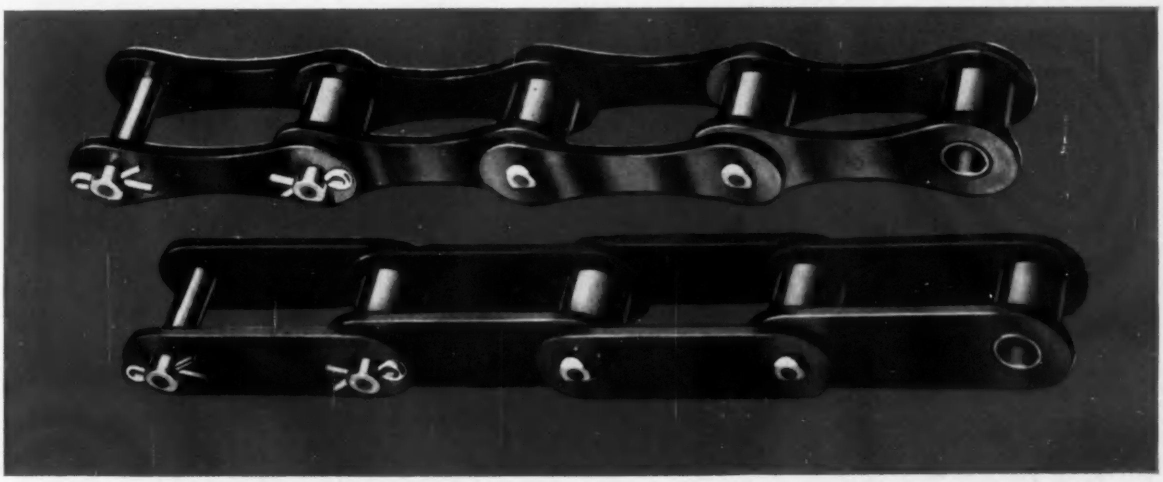
Hartley W. Barclay, Robert F. Dunlop, Fred B. Fischl, Pierre John Haan, John C. Harvey, Jr., Stephen Katzko, R. A. Keckeissen, Kenneth Langridge, Sol. Martin Schusheim, Robert L. Swick, Raymond Warell, William M. J. Wiehl.

Continued





Cutaway shows exclusive Morflex neoprene biscuit at each end of PTO driveshaft.



Top: Morse Implement-Conveyor Roller Chain, Power-Transmission Series; Bottom: Conveyor Series

Applications Received
Continued

Mid-Continent Section
William T. O'Shields, Melvin E. Putnam.

Mid-Michigan Section
James L. Byrne, Ralph E. Frick, Charles E. Schalla.

Milwaukee Section
Richard Jasensky, Glenn J. LaZotte, Douglas Matthew Waisanen.

Montreal Section
Rene Carbonneau, Lee M. Yarberry.

New England Section
Robert E. Fitzgerald.

Northern California Section
Robert W. Goode, Gene D. Schott, Edward Masao Takemori.

Nothwest Section
William Fred Anderson.

Oregon Section
Bernt Johnson, Dale Malvin Ott.

Philadelphia Section
George F. Bittner, Elliot J. Parker, Luke L. Stager.

Pittsburgh Section
William R. Hartman.

St. Louis Section
Albert Edward Cawns.

San Diego Section
Richard A. Schneeloch, Floyd E. Zimmerman.

Southern California Section
Wilson A. Burtis, Wilbert Merritt Gilroy, Frank D. Hartzell, Daniel S. Izzo, Robert S. Kirksey, Douglas M. Longyear, David Ronald Lundquist, Jack Weston McKeehan, Herman G. Preyer, Donald E. Stibich, Walden M. Zittle.

Southern New England Section
Angelo J. Introvigne, William Finley Laverty, Donuad R. Riccio.

Spokane-Intermountain Section
J. E. McKay.

Syracuse Section
Robert J. Heinzman.

Texas Section
Robert W. Burden.

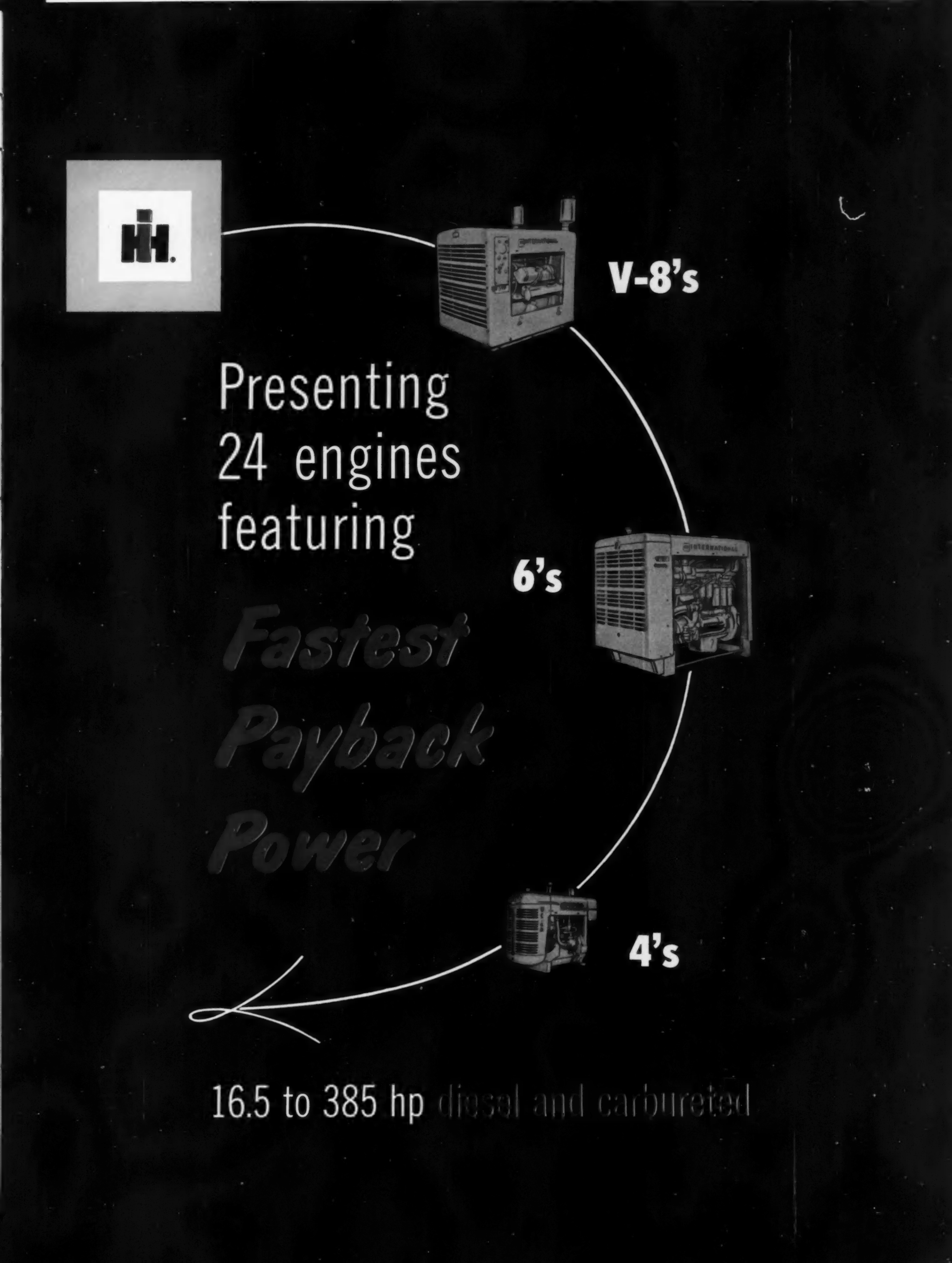
Washington Section
Robert B. Reichert.

Western Michigan Section
Bryan Betz, Russell E. Cribbs, Henry S. Elliott, Floyd K. McGahan, Clement E. Naperala, Gordon E. Reynolds Charles F. Rodgers, Lee H. Saylor, Charles R. Stuart, George Richard Wilson.

Williamsport Group
Frederick W. Long.

Outside Section Territory
James Sidney Freers, Paul Neher, Newton N. Sacks.

Foreign
Mohamed Osman Abdel-Moneim, Africa; Richard Erwin Albury, Venezuela; Franz Josef Hendriksen, Jamaica British West Indies; Calvin Harry Johns, Argentina; Tummala Sree Krishna Murty, India; Thomas Molnar, Australia.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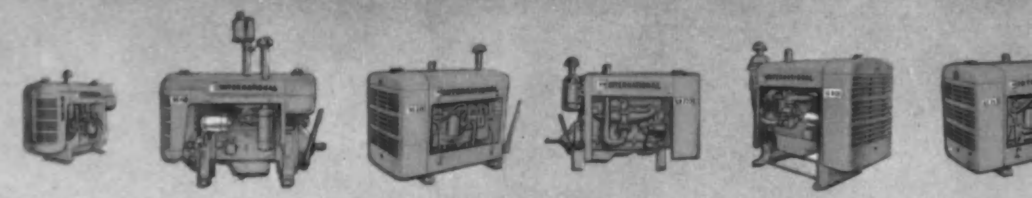
V-8's
Presenting
24 engines
featuring
6's
Fastest
Payback
Power
4's
16.5 to 385 hp diesel and carbureted



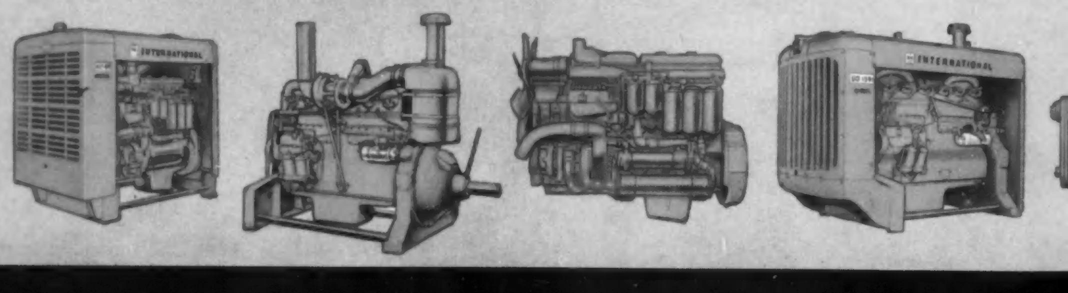
UC-60 16.5 max. eng. hp | **UC-135** 42 max. eng. hp | **UC-221** 75 max. eng. hp | **UB-220** 83 max. eng. hp | **U-308** 92 max. eng. hp | **UC-263** 95 max. en

TEAR OUT AND FILE

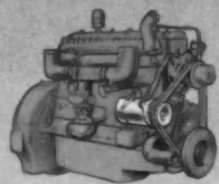
WITH INTERNATIONAL

Fastest Payback Pow

UDT-817 375 int. eng. hp | **UDT-1091** 265 int. eng. hp | **UD-817** 240 int. eng. hp | **UD-1091** 216 int. eng. hp

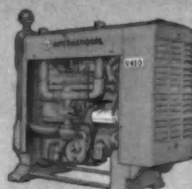


UC-263
95 max. eng. hp

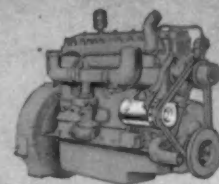


U-372
110 max. eng. hp

UB-264
112 max. eng. hp



U-450
134.5 max. eng. hp



U-501
141 max. eng. hp

ower

starts in your product's engine

Your new products can beat competition by paying for themselves faster on the job. And by specifying International, you can make sure fastest payback power starts in your product's engine.

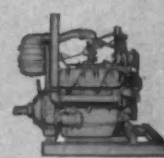
International engineers with over a half century of heavy-duty engine design experience make fastest payback power the common feature of all International engines through lowest cost operation, long-working stamina, superior sealing, and minimum maintenance.

And it's so easy costwise to match International power exactly to your product without overpowering or underpowering. Choose from 24 models from 16.5 to 385 max. hp. Choose the desired fuel from 10 diesels and 14 natural gas, LPG or gasoline carbureted models in 4's, 6's, and V-8's.

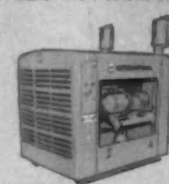
All 24 models are available from stripped engines to complete power units. A wide variety of accessory equipment including air cleaners, flywheels for leading makes of torque converters and clutches, torque converter coolers, air compressors, safety shut-offs, instruments and engine controls can be furnished for your installation requirements. Bases, radiators, hoods and dashes, clutches and power take-offs can be ordered for complete power units.

Your request for more specific information or installation assistance will get immediate attention. Just write or call International Harvester Co., Engine Sales Dept., Construction Equipment Division, Melrose Park, Ill.

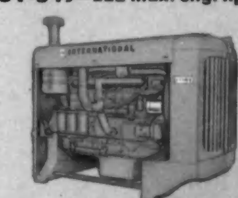
UV-401—170 max. eng. hp



UV-461—179 max. eng. hp



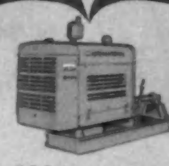
UV-549—222 max. eng. hp



U-1091—248 max. eng. hp
(nat. gas)

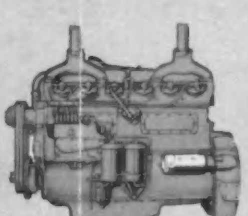
CARBURETED

DIESEL

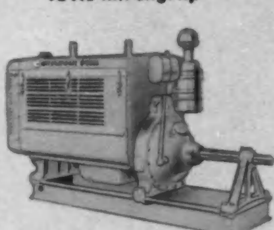


UD-236—70 int. eng. hp

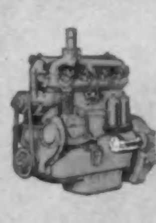
. hp



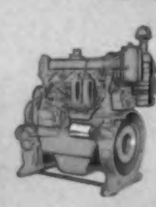
UD-554
140 int. eng. hp



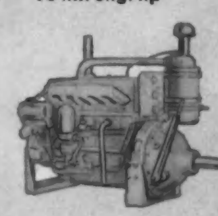
UD-18A
131.5 int. eng. hp



UD-14A
105 int. eng. hp



UD-370
95 int. eng. hp



UD-282
90 int. eng. hp

Your choice of engine sizes and fuels, all with *Fastest Payback Power*

Your International Power Selector

CARBURETED	MODEL	RATED RPM	CU. IN. DISPLACEMENT	GASO. HP	LPG HP	NAT. GAS HP
FOURS	UC-60	2500	60	16.8		
	UC-135	2000	135	42	42	32
SIXES	UC-221	2400	221	75	75	66
	UB-220		220	83	83	70
	U-308	2400	308	92	96	82.5
	UC-263	2400	263	95	95	85
	U-372	2200	372	110	101	92.5
	UB-264		264	112	112	90
	U-450	2200	450	134.5	130.5	112
	U-501	2200	501	141	134	120
V-EIGHTS	UV-401	2800	401	170	165	142
	UV-461	2600	461	179	175	162
	UV-549	2600	549	222	215	192

DIESEL	MODEL	RATED RPM	CU. IN. DISPLACEMENT	MAX. TORQUE AND RPM	BORE X STROKE IN.	INTERMITTENT HP
FOURS	UD-370	2200	370	262 @ 1400	4⅝ x 5½	95
	UD-14A	1800	460.7	325 @ 900	4¾ x 6½	105
SIXES	UD-236	2400	236	173 @ 1800	$3\frac{11}{16}$ x $3\frac{11}{16}$	70
	UD-282	2400	282	217 @ 1800	$3\frac{11}{16}$ x 4.39	90
	UD-554	2300	554	400 @ 1300	4⅝ x 5½	140
	UD-18A	1600	691.1	473 @ 850	4¾ x 6½	131.5
	UD-1091	1500	1090.6	825 @ 1150	5¾ x 7	216
	UDT-1091	1500	1090.6	1000 @ 1250	5¾ x 7	265
	UD-817	2100	817	638 @ 1600	5⅜ x 6	240
	UDT-817	2100	817	1052 @ 1200	5⅜ x 6	375

NOTE: *For carbureted engines use 90% of max. hp shown for intermittent type application and 80% of max. hp for continuous type application. For diesel engines use 80% of intermittent hp shown for continuous duty application.*

Specifications subject to change without notice.

International® Construction Equipment

A COMPLETE POWER PACKAGE: Crawler and Wheel Tractors . . . Self-Propelled Scrapers and Bottom-Dump Wagons . . . Crawler and Rubber-Tired Loaders . . . Off-Highway Haulers . . . Diesel and Carbureted Engines . . . Motor Trucks . . . Farm Tractors and Equipment.

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YEARS-AHEAD RESEARCH *ASSURES* CUSTOMERS OF LATEST CARBURETOR ADVANCES TODAY!

New High In Carburetor Reliability!

Today, at the General Motors Technical Center and at Rochester, engineers are busy tracking down carburetor trouble. This means your customers can travel thousands of trouble-free miles, enjoying peak performance and economy. This extra assurance of satisfaction is only part of the rigid quality control that goes into a Rochester-GM Carburetor. Summer conditions are anticipated through millions of tough test miles in Arizona, and Winter tests are made in other parts of the nation. When Rochester-GM Carburetors are finally delivered, they have trouble tested out . . . and reliability built in. So, keep an eye on your customer's satisfaction . . . keep a Rochester-GM Carburetor on his car. *Rochester Products Division of General Motors, Rochester, New York.*

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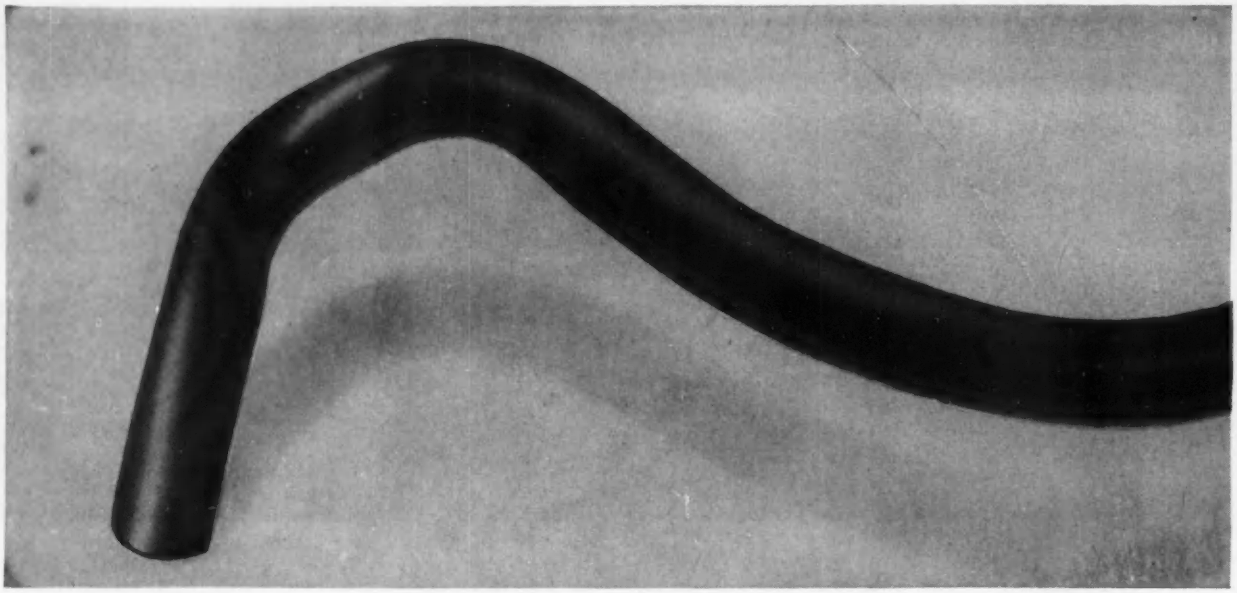
GENERAL MOTORS

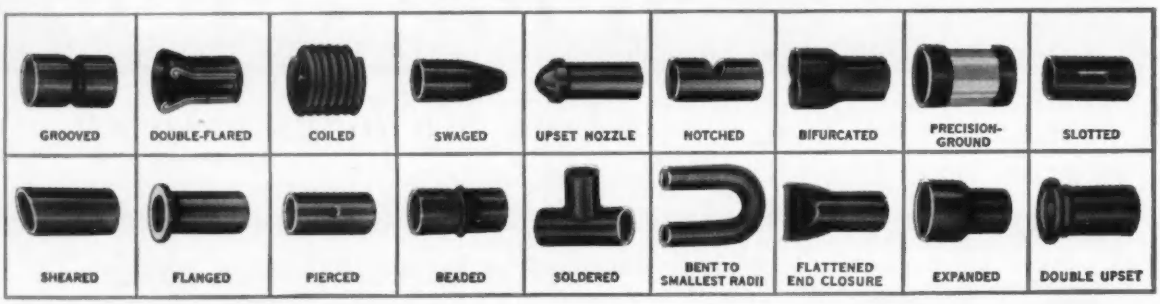
BETTER-BUILT FOR CADILLAC, BUICK, OLDSMOBILE, PONTIAC AND CHEVROLET



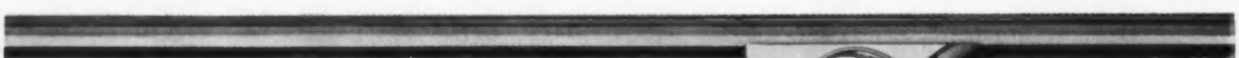
Multiple-bend discharge tube for refrigeration compressor is fabricated quickly, economically on Bundy-designed fixtures. Seven bends are put into a 7" length of ¼ x .028" Bundyweld in just one semi-automatic operation.

BUNDYWELD...BENT

TYPICAL FABRICATION OPERATIONS POSSIBLE WITH BUNDYWELD TUBING



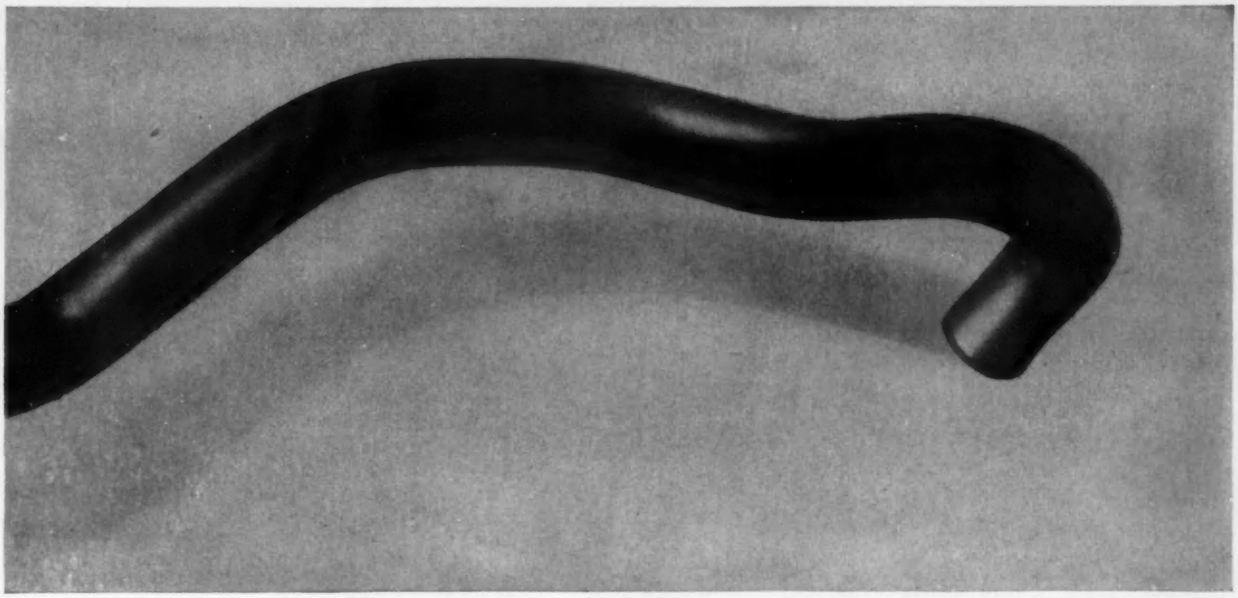
Shown above are but a *few* of the fabrication operations possible with Bundyweld Steel Tubing. Many of these — and others not shown — were developed through solving a specific problem brought to us by a customer or prospect. At any stage in the development of your product, Bundy invites you to take advantage of this design service.

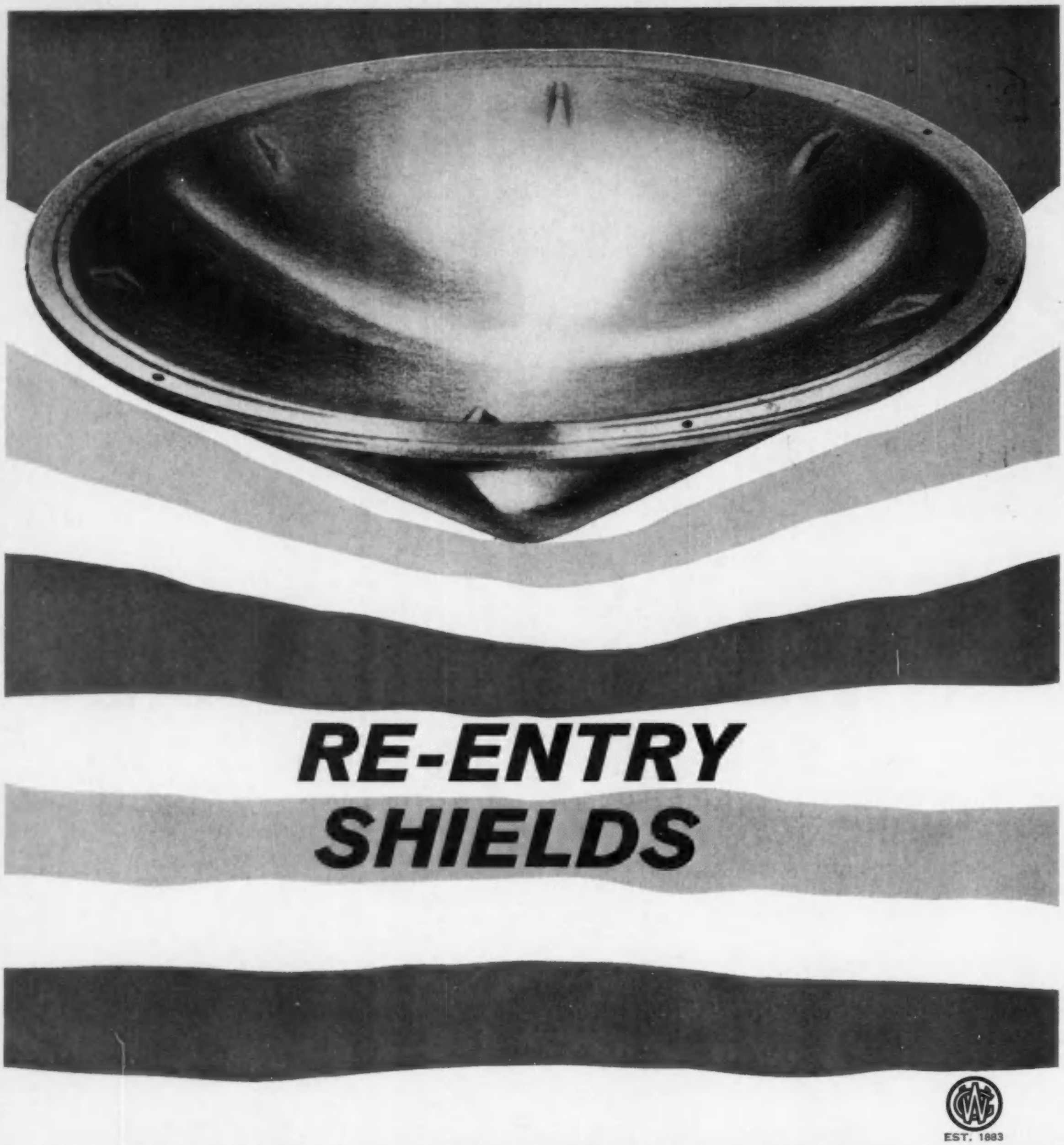


BUNDYWELD IS DOUBLE-WALLED FROM A SINGLE STRIP

Bundyweld starts as a single strip of copper-coated steel. Then it's . . . continuously rolled twice around laterally into a tube of uniform thickness, and passed through a furnace. Copper coating fuses with steel. Result . . . Bundyweld, double-walled and brazed through 360° of wall contact.

← **NOTE** the exclusive Bundy-developed beveled edges, which afford a smoother joint, absence of bead, and less chance for any leakage.





WYMAN-GORDON IS FORGING RE-ENTRY SHIELDS

- Copper in production
- Beryllium in limited production
- Reinforced plastics in development

WYMAN-GORDON

FORGING

ALUMINUM MAGNESIUM STEEL TITANIUM BERYLLIUM MOLYBDENUM COLUMBIUM
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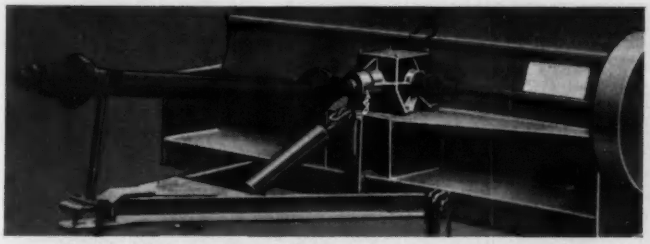
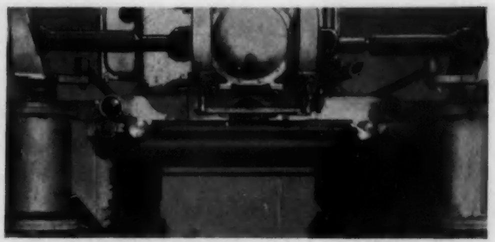
WORCESTER, MASSACHUSETTS

HARVEY, ILLINOIS GRAFTON, MASSACHUSETTS FRANKLIN PARK, ILLINOIS
DETROIT, MICHIGAN FORT WORTH, TEXAS LOS ANGELES, CALIFORNIA

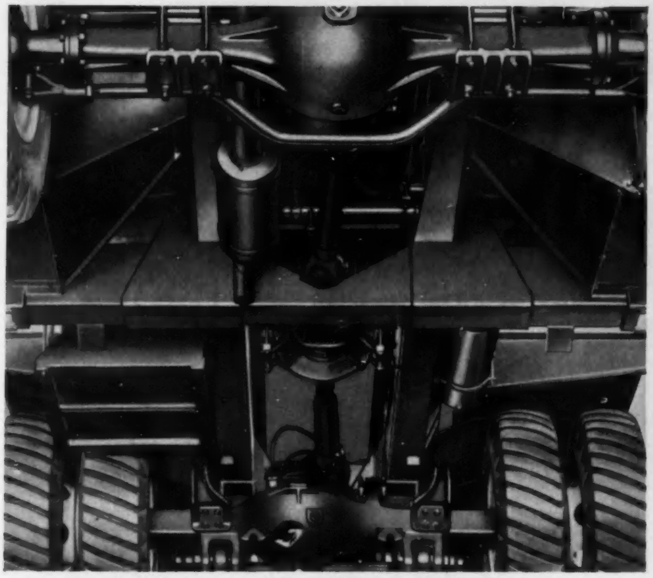
Photograph by Telegraph & Argus, Bradford.



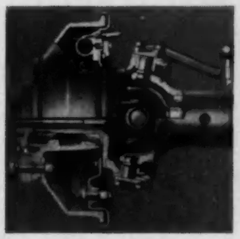
Shielded Farm Implement Drive, Tractor P.T.O. to Gear Box



Differential to Drive Sprocket, Straddle Truck

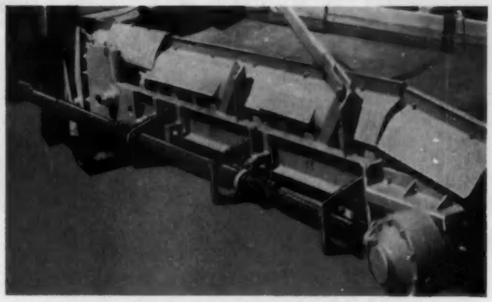


Mobile Crane, All-Wheel Drive Propeller Shafts



Jointed Front-Driving Axle

High Angle, Double Joints



Road Grader, Detachable Belt Conveyor Drive

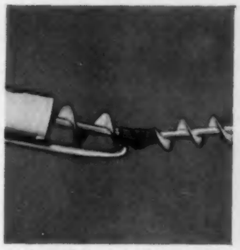
POWER TRANSMISSION PROBLEMS SOLVED

with Blood Brothers U-Joints

Rockwell-Standard engineers see—and help *solve*—a tremendous variety of problems involving a need for universal joints. Applications range from manual steering assemblies...to power take-off drives...to heavy duty propeller shafts.

To "get the power through," Blood Brothers Joints are built in the widest range of types and sizes. This range, plus application experience, can be valuable to you. Whether you want to "take power around corners"...or allow for possible minor misalignments—you can call on Rockwell-Standard engineers.

They'll cooperate to save your staff's time — on common or unusual power transmission problems.



Jointed Screw Conveyor

Tractor Steering Assembly

Transmission P.T.O. Drives Pump and Gear Box

ROCKWELL-STANDARD CORPORATION

ROCKWELL R STANDARD

BB UNIVERSAL JOINTS

Blood Brothers Universal Joints

ALLEGAN, MICHIGAN

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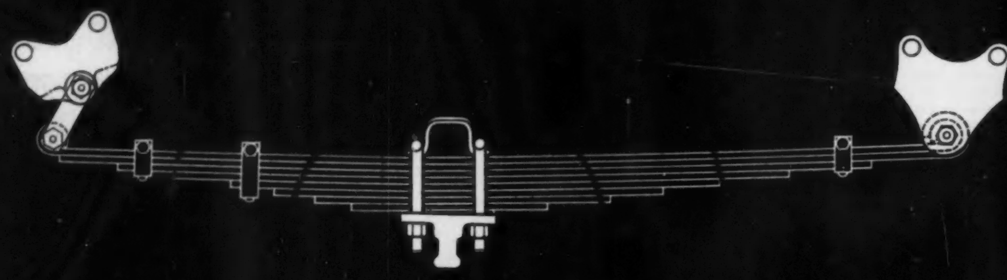


a "BUILT-IN" Feature of Leaf Springs

Three-point suspension at shackle, hanger, and axle provides "CRADLE-SAFETY," functional for the life of the springs.

This suspension provides perfect balance, alignment, and sidesway control . . . safety functions performed naturally and efficiently by leaf springs — *well designed.*

DSP
Leaf
SPRINGS

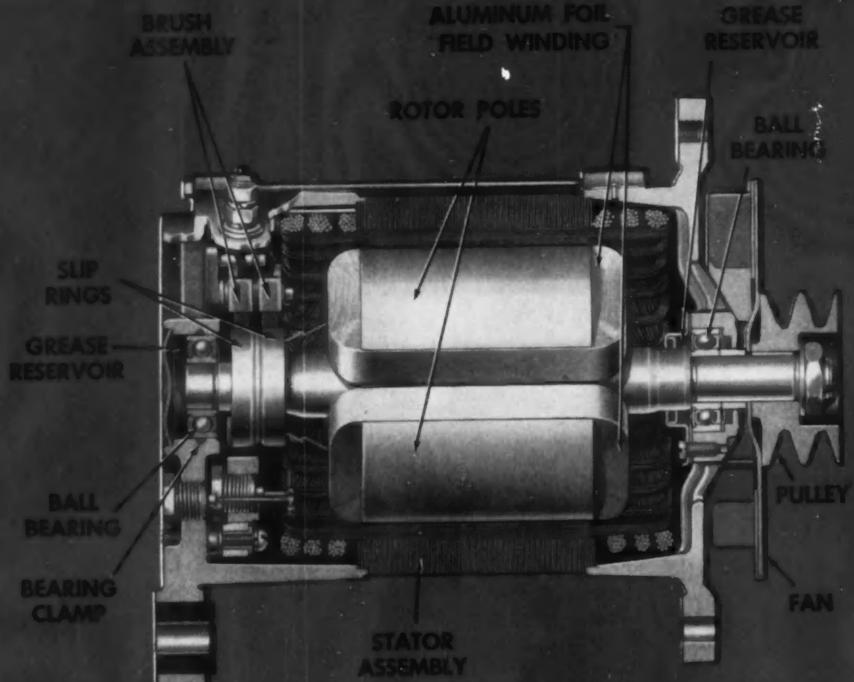
DETROIT STEEL PRODUCTS DIVISION

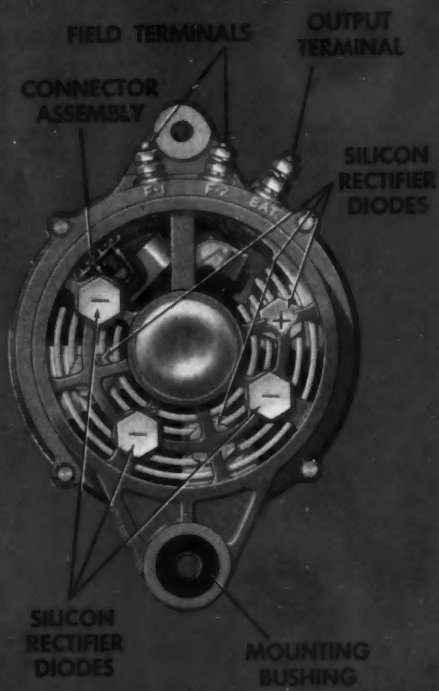
OF *Fenestra* INCORPORATED

6000 Caniff Avenue, Detroit 12, Michigan

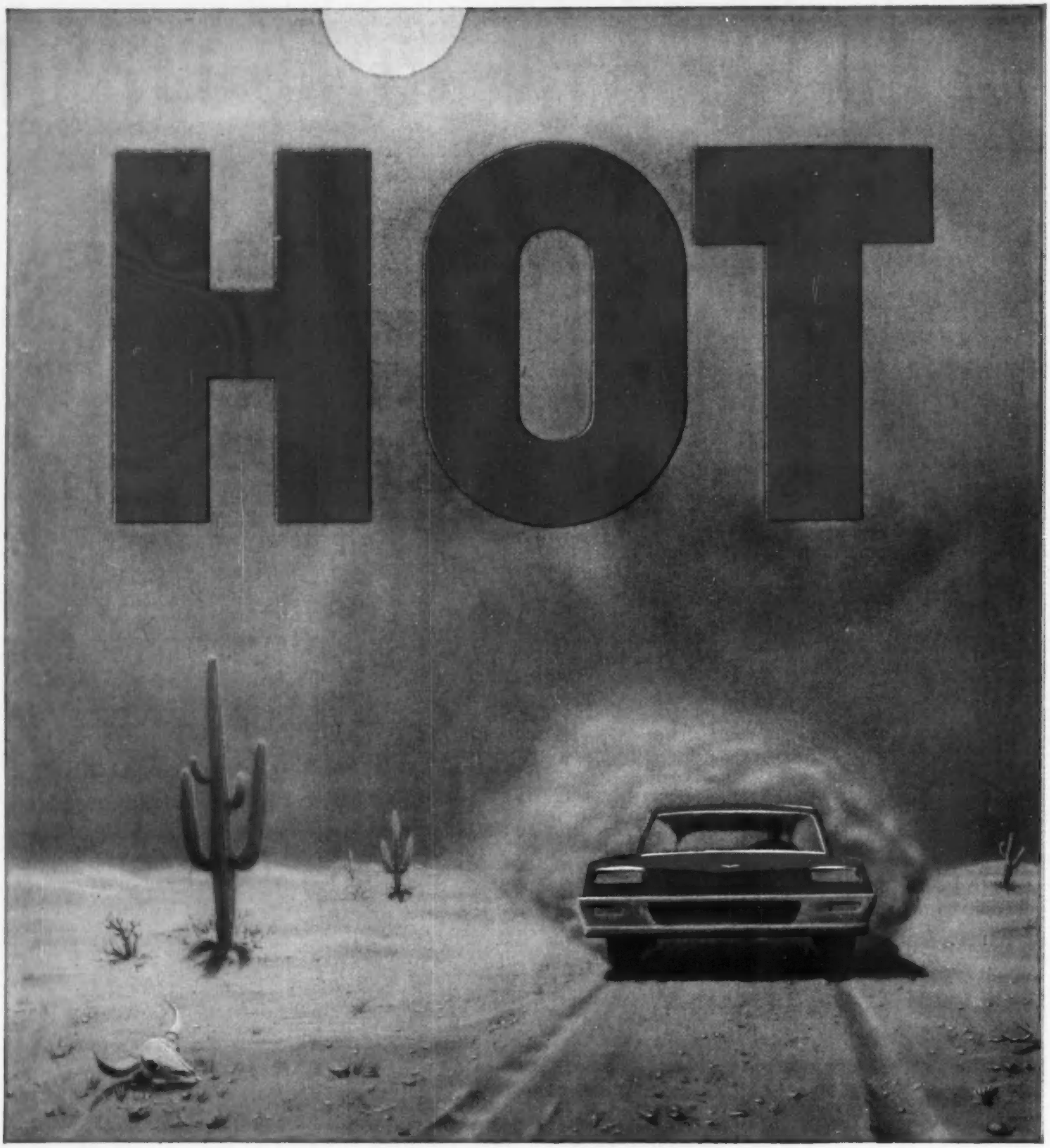
since 1904—original equipment on cars, trucks, cabs, buses, trailers

NOW! REAL CHARGE-AT-IDLE,





PROGRESSIVE
ENGINEERING
MAKES
THE
DIFFERENCE

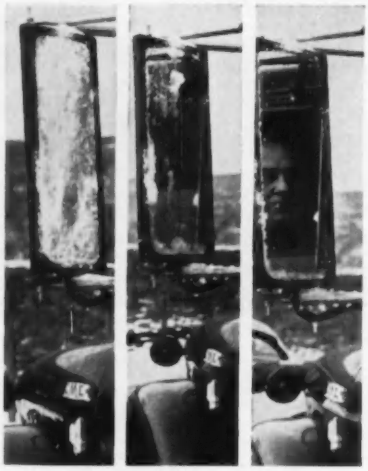

HOT

THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

NEW! A MIRROR THAT MAKES HEAT TO BEAT SLEET

You're jockeying a big trailer-truck along a winding road in New England. It's winter and you run into a real storm—a mixture of snow, rain, sleet. You flip a switch and . . .



Your outside rear-view mirror is *clear* in a matter of minutes. From a heavy coating of ice to *all* clear is only a matter of five minutes, even at −20°F.

The mirror, as you might guess, isn't just ordinary glass. It's one of Corning's PYREX brand glasses, and on its surface is an electrically conductive coating that's permanently fired in.

This coating (a metallic oxide) is what turns your mirror into a *heating* element when a current is applied. The heat melts ice and snow, prevents fog or drizzle from condensing on the surface.

If you use EC (electrical-conducting) glass for self-defrosting mirrors you get a bonus, since the coating also provides a non-glare surface.

But don't go away just because you gave up dreaming about driving a truck-and-trailer years ago. This PYREX® electrical-conducting glass comes in a wide choice of applications.

For example, there are some enterprising people who build radiant heaters, both portable and permanent, around such glass panels.

Comfort, safety, and convenience are the big selling points. Comfort because a panel of EC glass is an area *heat* source putting out long waves. Safety because there are no exposed wires or moving parts. Convenience since you have no burning, no need to do extensive remodeling in order to install it.

These same reasons have made PYREX brand radiant heating units attractive to industry—for heating, drying, curing, baking.

And, if you turn a panel of this glass *around*, it becomes an infrared reflector you can see through—blocking heat but still passing about 75% of the visible light.

Facts? Ask for PE-34, a 4-page data sheet, and/or PE-60, all about industrial heating units. Please use the coupon.

YOU ARE CORDIALLY INVITED

. . . to visit the Corning Glass Center located in Corning, in the rolling hills just south of New York State's Finger Lakes region. The Center is dedicated to the history, science, art, and industry of glassmaking.

Among the Center's most-visited attractions are the Corning Museum of Glass and the Hall of Science and Industry.

At the Museum you'll find a comprehensive and renowned collection of glass *objets d'art*. You will find vases and other glass forms produced by by-gone civilizations. And you will see the ways in which today's craftsmen, around the world, use glass in varied art forms.

The Hall of Science and Industry is filled with exhibits and devoted to the roles glass plays in industry, business, and science. Many exhibits contain full-scale working models and demonstrations.

And, there's also a library devoted exclusively to books and other reference materials on glass.

It all awaits you. So come to the Glass Center. You'll find it stimulating and rewarding. Bring the family, too. You'll all enjoy the trip.

Open daily except Mondays from 9:30 to 5.

If you'd like a few more facts, send for a free folder. But plan to come soon.

HOW TO GET A RECTANGULAR BEAM FROM A ROUND LENS

This is no ordinary floodlight lens. It produces, despite its circular shape, a rectangular beam.

Why? Because a large oil company asked Crouse-Hinds of Syracuse, N. Y., to provide a floodlight to illuminate rectangular signs, 4′ x 8′. Besides being rectangular, the request called for lighting that had no "hot spot" which might make the sign unreadable.

So Crouse-Hinds turned to Corning. And through the talents of one of our product engineers, we designed a *round* lens that puts out a rectangular beam.

Unusual? Yes, but typical of the special problems we handle almost daily (we once made a lens producing a square beam for the same people).

Moral: Whatever your interest—be it lighting, corrosion, high temperatures, precision shaping, or what have you—maybe we already make what you need from glass.

As a start, take a look through "This Is Glass." (To get a copy, check the coupon.)

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS 40 Crystal Street, Corning, N.Y.

Please send me: ☐ PE-34, 4-page data sheet on glasses for industrial use; ☐ PE-60, booklet on heating units; ☐ Brochure on the Glass Center; ☐ "This Is Glass"

Name____________ Title____________

Company____________

Street____________

City____________ Zone____ State________

World's first "screech-free" tire!

GIVES CARS MANY NEW SELLING FEATURES

Since Enjay Butyl absorbs shock better than any other rubber, tires made from this amazing rubber offer revolutionary improvements in the riding and handling characteristics of any car. They eliminate, or at least minimize, major engineering changes to overcome vibration and noise. Tires of Butyl provide all these riding qualities—for any car:

- **The BUTYL RIDE** is safer . . . stopping distances have been reduced as much as 30%. Butyl tires *even stop faster on wet surfaces than other tires do on dry.*
- **The BUTYL RIDE** is smoother . . . tires of Butyl tend to flow over road irregularities – shock absorbent ride practically eliminates road-seam "thumping".
- **The BUTYL RIDE** is quieter...you can't make Butyl tires screech at any corner, at any speed—even in panic stops. Running noise and vibration are measurably reduced.
- **And BUTYL TIRES** resist ozone, sunlight and weathering. After long service, sidewalls keep their shiny "new-tire look," are virtually immune to cracking, aging.

Let us show you how tires of Butyl can help you sell more cars. *For complete information* . . . write or phone your nearest Enjay office. Our expert staff is always willing to provide information and technical assistance upon request.

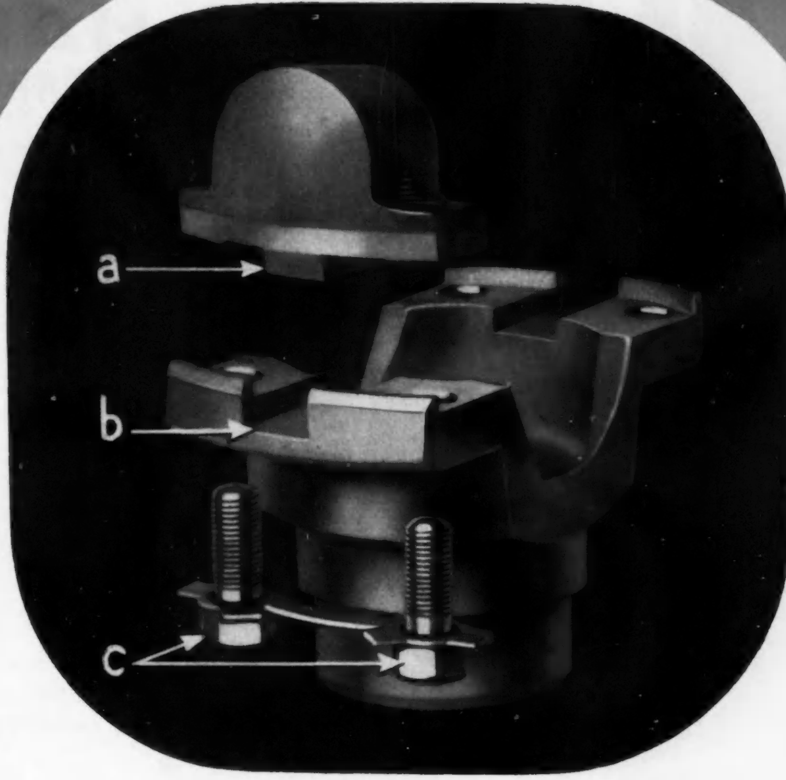
EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY BUTYL

ENJAY COMPANY, INC., *15 West 51st St., New York 19, N. Y. Akron • Boston • Charlotte • Chicago • Detroit • Los Angeles • New Orleans • Tulsa*

Avoid Costly Delays

Keep Your Product ON the Job and OUT of the Shop with KEY Drive JOINTS

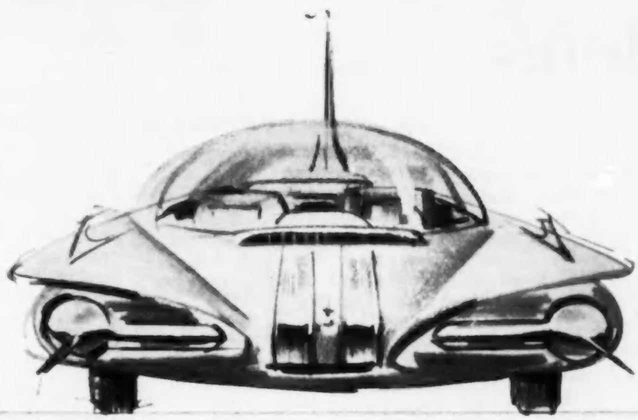


MECHANICS Roller Bearing UNIVERSAL JOINTS drive through hardened integral KEYS—not bolts nor screws that often wear loose. Heavy KEYS (a) on the bearings and corresponding keyways (b) in the flanges, accurately machined out of solid metal, transmit all of the torque. Two cap screws (c) hold each bearing securely in place against the flange. This is their only function. They are locked in position, when assembled, and have a high factor of safety. This stronger, safer, KEY method of transmitting the torque in MECHANICS Roller Bearing UNIVERSAL JOINTS helps avoid costly delays, break-downs and unnecessarily frequent laying-up for joint replacements. Let our engineers show you how this exclusive MECHANICS Roller Bearing UNIVERSAL JOINTS advantage will help improve the operation of your product.

MECHANICS UNIVERSAL JOINT DIVISION

Borg-Warner • 2022 Harrison Ave., Rockford, Ill.

Export Sales: Borg-Warner International
36 So. Wabash, Chicago 3, Illinois



PUROLATOR'S DRY TYPE AIR FILTERS GIVE

COMPLETE DESIGN FREEDOM

With Purolator's new dry type air filters, there's no need to keep a constant, level bearing . . . to set the air cleaner on top of the block. There is no oil to spill, no level to be maintained. This makes it possible to place the filter anywhere at all . . . under the engine, on the side . . . wherever it allows the most design freedom.

Of course, the big advantage in dry type filtration is the optimum efficiency it affords. The Micronic dry type element is just as effective at low speeds as at high speeds. And instead of becoming less efficient with use, its already outstanding 99% efficiency *increases* to 99.7%.

Design your cars the way you want them . . . then call on Purolator to design and produce the air filter to fit your design.

Filtration For Every Known Fluid **PUROLATOR**
PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, ONTARIO, CANADA

Hypoid Single-Reduction Gears Make TIMKEN-DETROIT® LIGHTWEIGHT TANDEMS FIRST CHOICE

for plus-profit payloads!

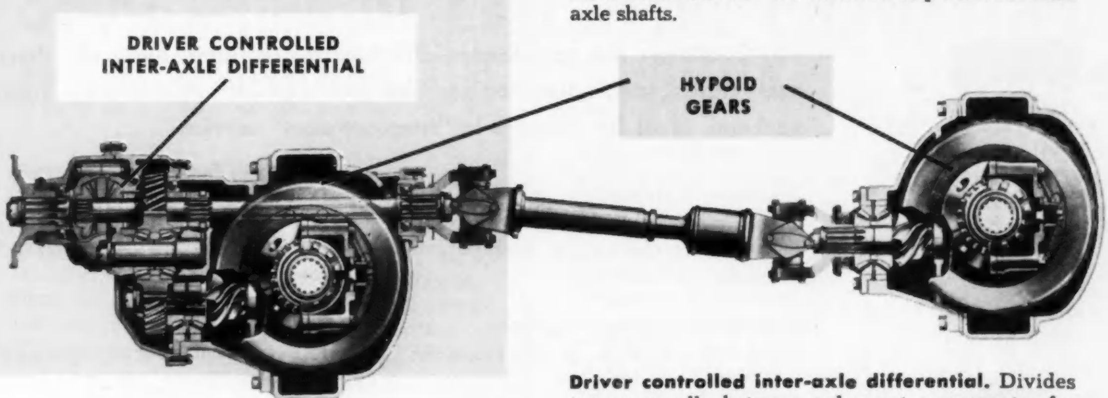
For more than three years Timken-Detroit Lightweight Tandems with Hypoid Single-Reduction Gears have been *first choice* with over-the-highway operators. Here are some of the reasons why:

Up to 700 lbs. lighter. Lighter in weight than other tandems currently available, Timken-Detroit's efficiency of design is unmatched in the industry. This not only means lower initial cost but *greater revenue from every payload.*

Hypoid gearing. Provides up to 30% more strength than spiral bevel gearing of the same size. Stronger design gives longer life and lower maintenance costs. To match hypoid gear performance, a spiral bevel gear must be larger and heavier.

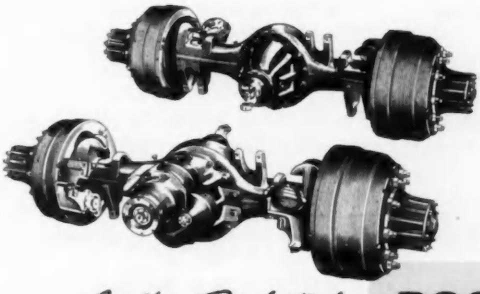
Widest choice of axle ratios. Because of the stronger hypoid gear set, it is practical to provide high numerical axle ratios up to 8.6 to 1. To provide axle ratios greater than approximately 7 to 1 with spiral bevel gearing, some form of auxiliary ratio multiplication is required. This increases both weight and cost.

"In-Line" through drive. Eliminates compound angles, and reduces drive line wear and maintenance. Differential carriers are centered to permit common axle shafts.



Driver controlled inter-axle differential. Divides torque equally between axles, yet compensates for any differential of speed between the axles. Both axles are always doing equal amounts of work. Can be locked out at any speed when poor traction conditions exist.

Tough, Torsion Flow Axle Shafts Are Best By Any Test. Don't be misled . . . patented Torsion Flow Axle Shafts are still the best available to the American Trucking Industry. Comparison tests prove that Timken-Detroit Axle Shafts, spline diameter for spline diameter, are the toughest ever made.



World's largest manufacturer of axles for trucks, buses and trailers

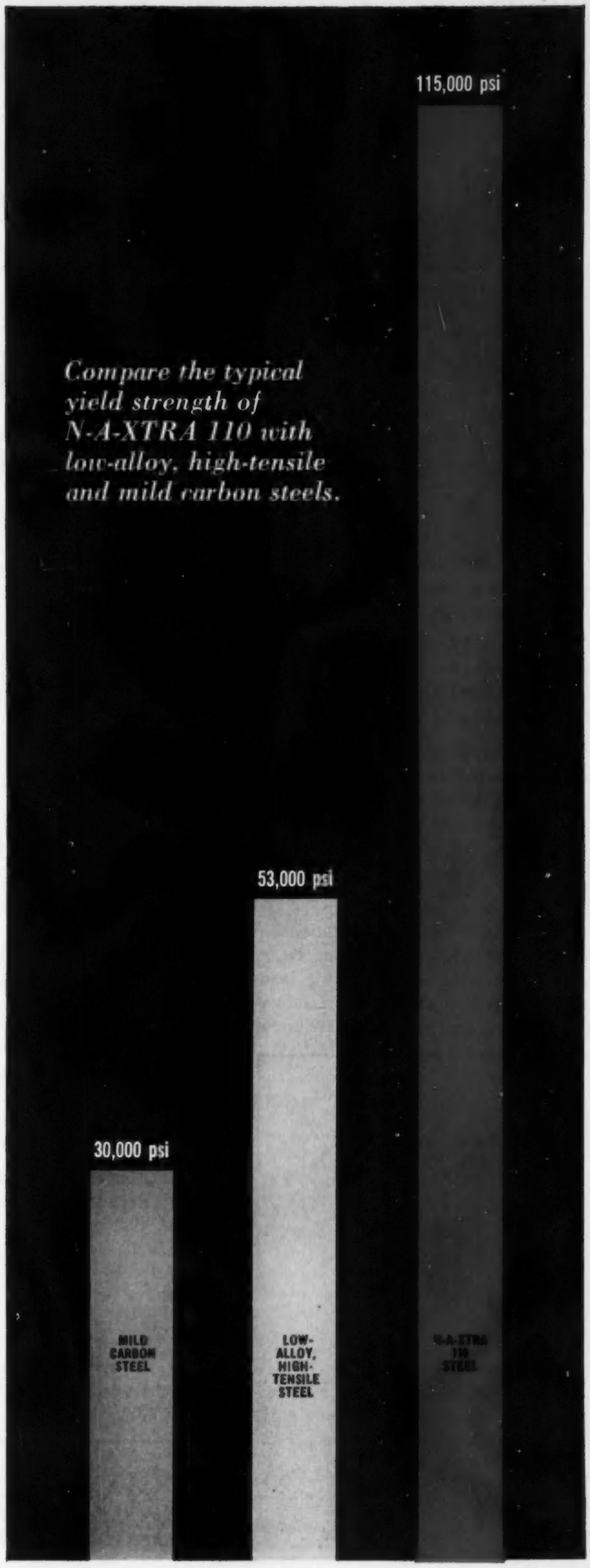
©1959, R-S Corp.

Another Product of...

ROCKWELL-STANDARD CORPORATION

ROCKWELL R STANDARD®

Transmission and Axle Division, Detroit 32, Michigan



Now available, N-A-XTRA HIGH-STRENGTH is a low-alloy heat-treated steel, fully quenched and tempered. The minimum yield strength range of N-A-XTRA steel is from 80,000 to 110,000 psi.

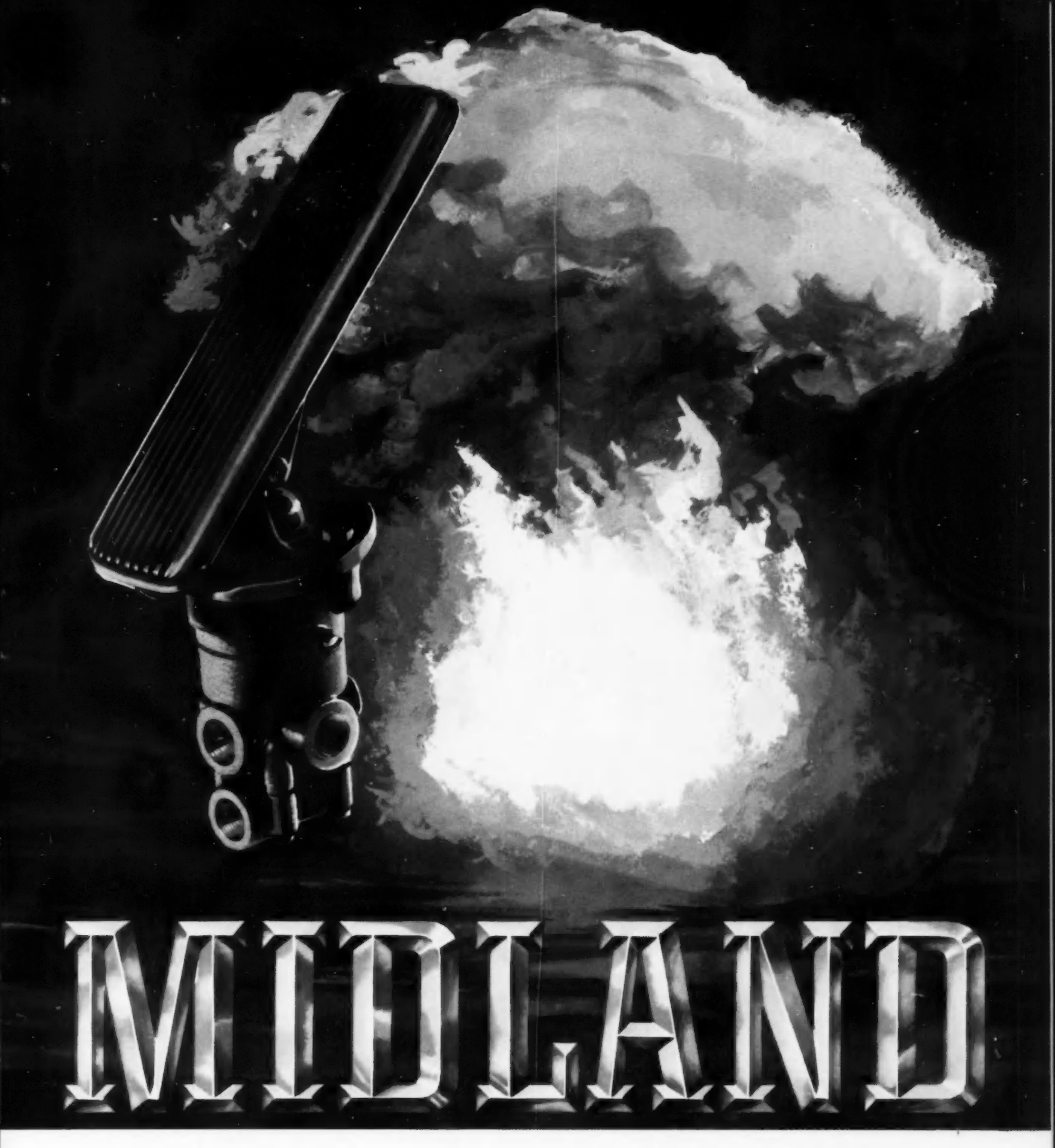
The great strength of N-A-XTRA (nearly three times that of mild carbon steels) gives designers the opportunity to eliminate costly dead weight from your products.

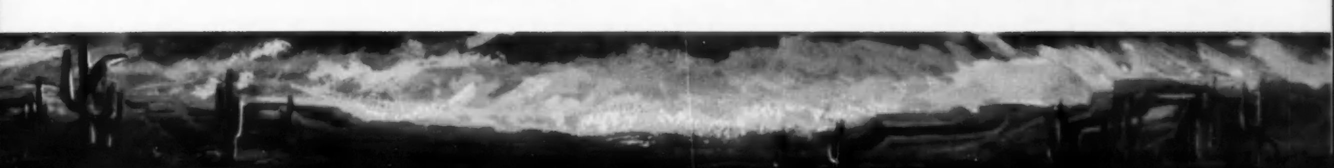
N-A-XTRA is tough at normal and subnormal temperatures. It can be readily cold formed into difficult shapes. And it welds beautifully by any process—with no underbead cracking. For a job where only the strongest of steels will do . . . specify N-A-XTRA HIGH-STRENGTH steel.

Write today for your copy of new illustrated technical brochure. Address Great Lakes Steel Corporation, Detroit 29, Michigan, Dept. F-6.

GREAT LAKES STEEL

A DIVISION OF NATIONAL STEEL CORPORATION


MIDLAND



NEW BENDIX-WESTINGHOUSE IS SAFER, FASTER, LIGHTER,

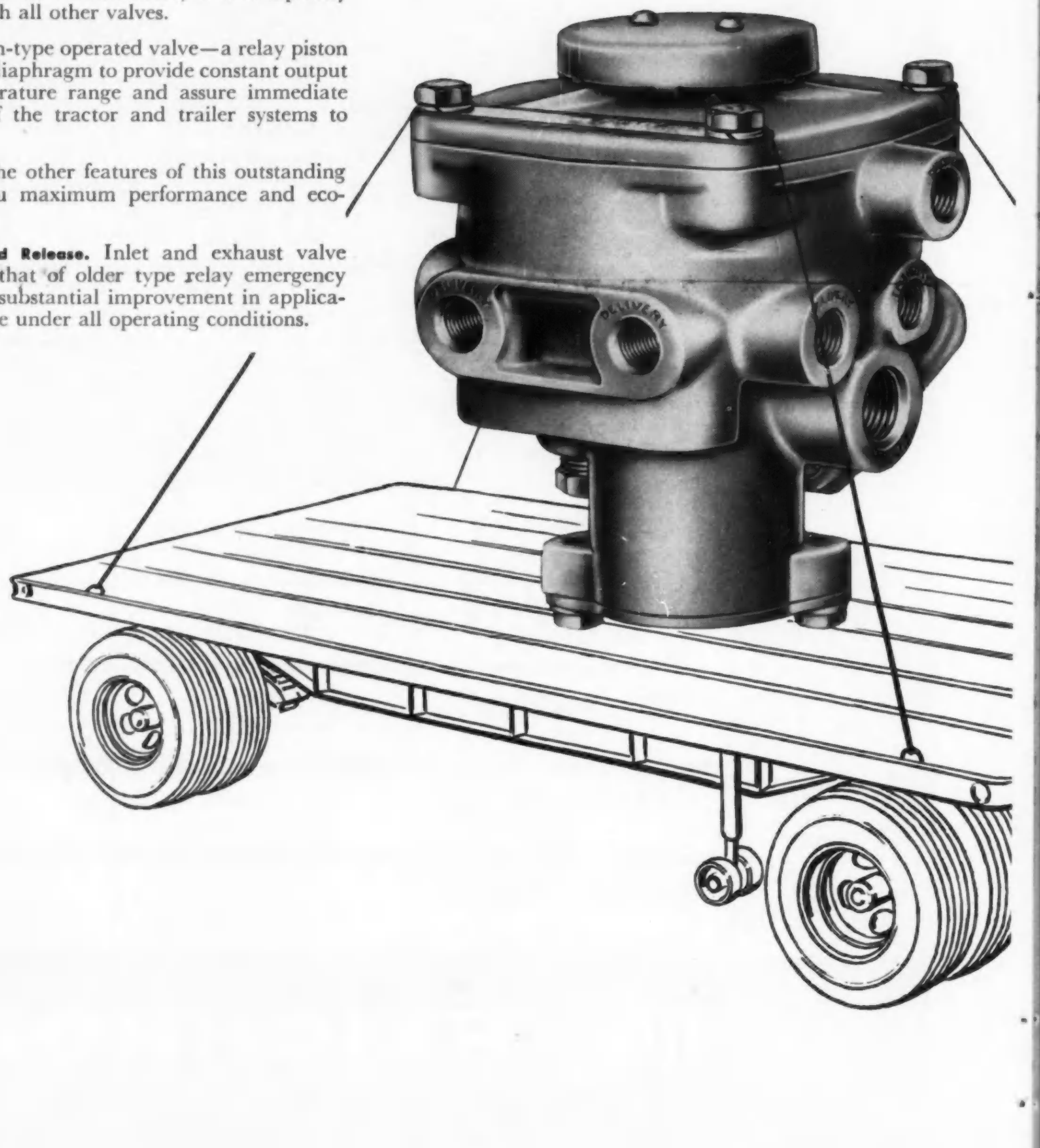
An important *new* link in the chain of devices that comprise an air brake system, the brand new Bendix-Westinghouse Relay Emergency Valve, Type RE-4, is now available for any trailer equipped with air brakes. Developed and perfected by the producer of the world's most widely used air brake systems, the RE-4 raises the already high standards of air brake safety and performance to the degree that it practically obsoletes all existing relay emergency valves. What's more, it is completely interchangeable with all other valves.

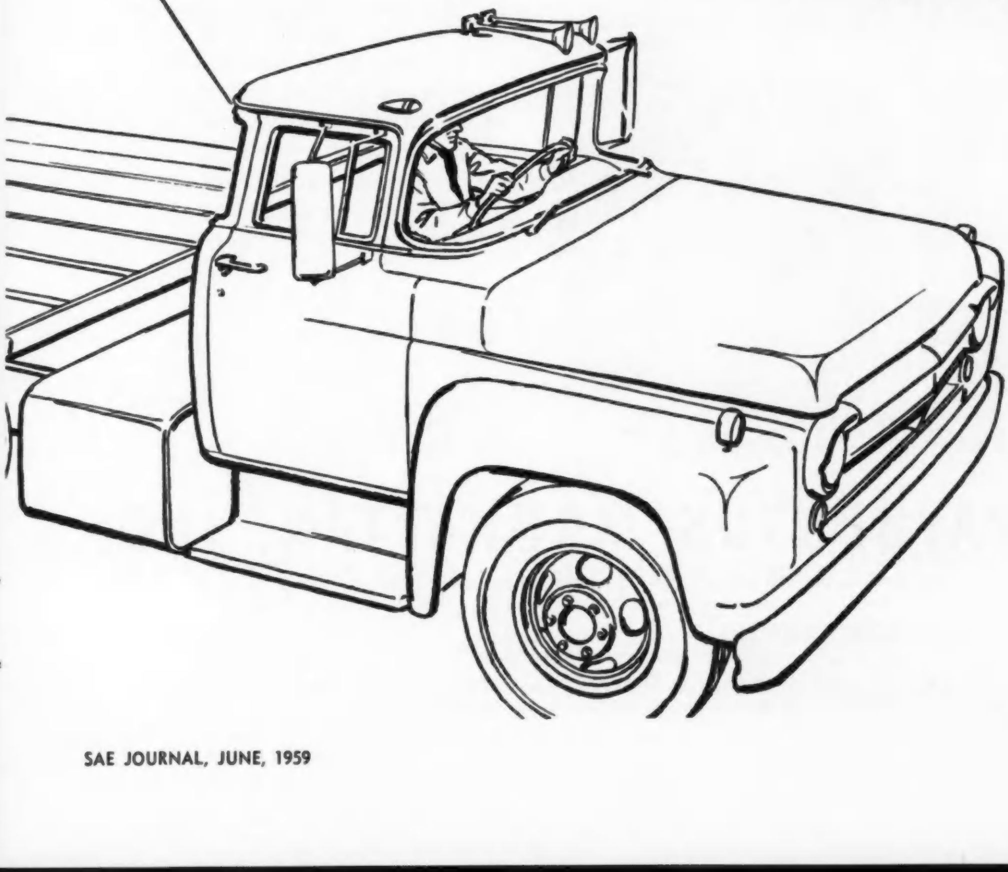
The RE-4 is a piston-type operated valve—a relay piston is used instead of a diaphragm to provide constant output over a wide temperature range and assure immediate pressure balance of the tractor and trailer systems to within 1 psi.

Here are some of the other features of this outstanding valve that give you maximum performance and economical operation.

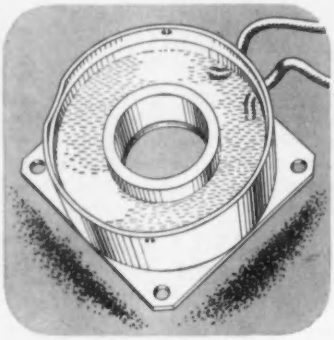
Faster Application and Release. Inlet and exhaust valve capacity is double that of older type relay emergency valves, providing a substantial improvement in application and release time under all operating conditions.

More Positive Action. In its normal function as a relay valve, the RE-4 provides a significant reduction in required "cracking" pressure needed for other types of relay emergency valves. Thus trailer brake application, especially in the lower delivery pressure range, is faster and better synchronized with tractor brake application.

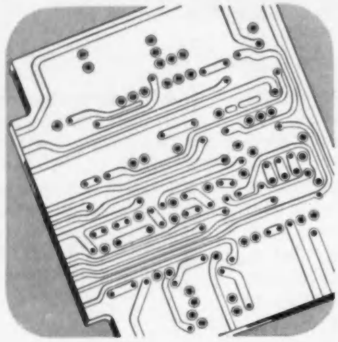




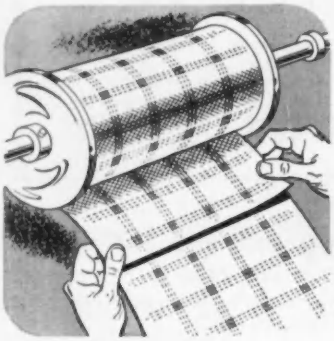
How you can cut time and costs with R/M *Ray-BOND*® Adhesives



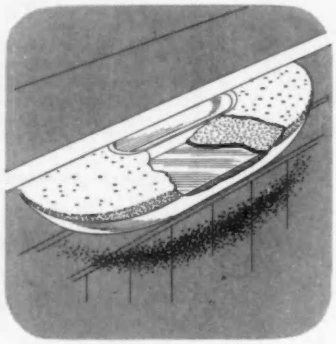
Casting compound for electrical applications



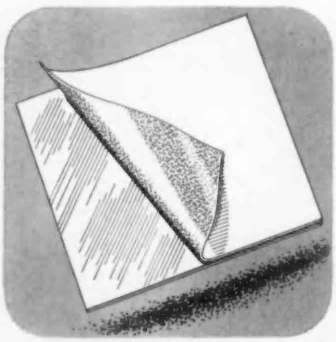
Bonding printed circuits



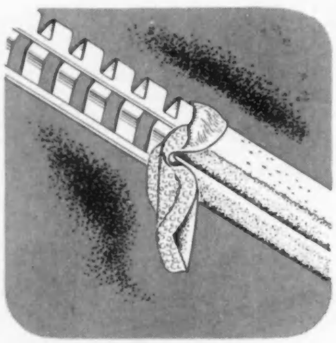
Bonding textile to textile



Bonding synthetic foam to metal in auto armrest



Bonding "Teflon"* to steel
*A Du Pont trademark



Sealer for automobile window channel

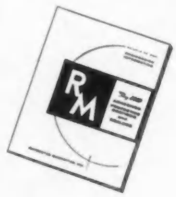
FOR THESE AND 1001 OTHER APPLICATIONS NEW R/M RAY-BOND ADHESIVES CAN BE TAILORED TO YOUR NEEDS

The number of new places you can use adhesives today is growing faster than ever. With new bonding techniques, with modern Ray-BOND adhesives, you can cut fastening time and costs in a variety of applications never possible before.

R/M Ray-BOND adhesives are of two different types—thermosetting and thermoplastic. They are available in different degrees of viscosity—for either spraying or painting. They give top performance under the most severe operating conditions—withstand temperature extremes ranging from –80° to +700°F.

Whether or not you've yet considered bonding, laminating, sealing or coating in your own operations, talk to an R/M engineer now. From over 20 years' pioneering in the production of bonded assemblies and the manufacture of adhesives and coatings, R/M has acquired a wealth of knowledge and experience that might help you find new ways to improve your product or cut costs. Write or call for complete information on new Ray-BOND adhesives now.

R/M Bulletin No. 700 contains engineering information you will want on Ray-BOND adhesives, protective coatings and sealers. Write for your free copy.



RAYBESTOS-MANHATTAN, INC.

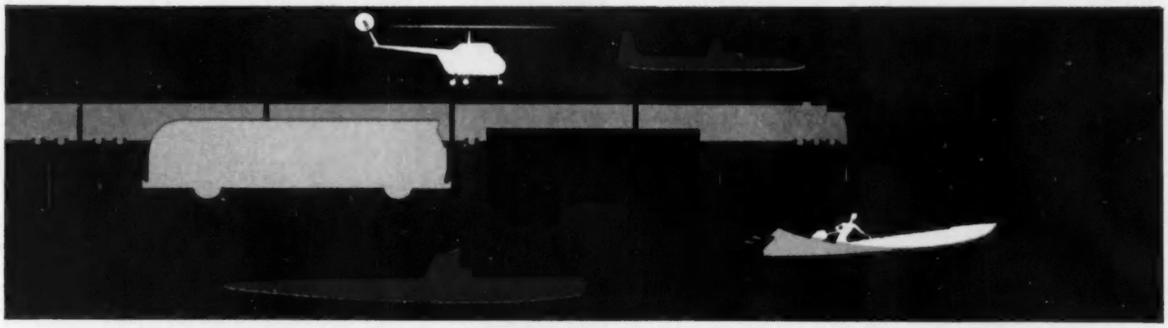
ADHESIVES DEPARTMENT: Bridgeport, Conn.

Chicago 31 • Detroit 2 • Cleveland 16 • Los Angeles 58

FACTORIES: Bridgeport, Conn.; Manheim, Pa.; Passaic, N.J.; No. Charleston, S.C.; Crawfordsville, Ind.; Neenah, Wis.; Paramount, Calif.
Raybestos-Manhattan (Canada) Limited, Peterborough, Ontario, Canada

RAYBESTOS-MANHATTAN, INC., Industrial Adhesives • Brake Linings • Brake Blocks • Clutch Facings • Industrial Rubber • Engineered Plastics • Sintered Metal Products
Rubber Covered Equipment • Asbestos Textiles • Laundry Pads and Covers • Packings • Abrasive and Diamond Wheels • Bowling Balls

WHEN IT COMES TO DRIVES



ON THESE TYPES OF INTERNAL COMBUSTION ENGINES

YOU START BETTER WITH BENDIX

For nearly fifty years Bendix* Starter Drives have been the recognized standard drive for all types of internal-combustion engines. Besides their more than 125,000,000 automotive installations, these units have also been given top preference in such diversified fields as aircraft, locomotives, earth movers, inboard and outboard marine engines. The reason *has* to be that Bendix drives deliver superior performance and are more reliable. In other words you can start *better* with Bendix.

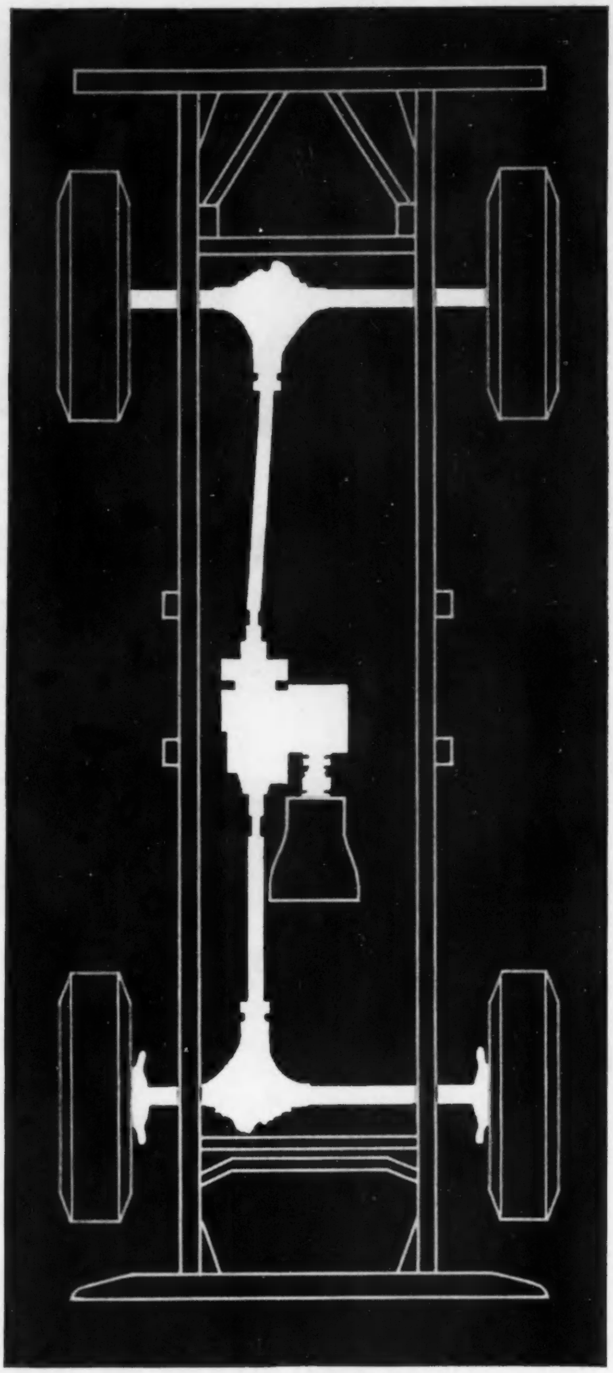
*REG. U.S. PAT. OFF.

Bendix-Elmira
ECLIPSE MACHINE DIVISION
ELMIRA, NEW YORK

Bendix
AVIATION CORPORATION

A DANA EXCLUSIVE...

Complete four-wheel drive assemblies



Only Dana has a complete . . . and power-matched . . . four-wheel drive assembly for almost any lightweight vehicle you produce. Just list your requirements and Dana will furnish the complete assembly, including front and rear driving axles, transfer case, propeller shafts and universal joints. And, since every component is designed to work together, you know the Spicer assembly will be power-matched to your specifications.

Axle length is never a problem because the Spicer design has the axle tubes pressed into the carrier housing. Thus you have a choice of hundreds of variations in axle length, wheel treads and spring seat arrangements plus either Cardan or constant-velocity wheel joints, as you prefer.

Make just one call . . . to the Dana engineer . . . when you're laying out a four-wheel drive design.

In the shortest possible time, he will coordinate the design of a complete four-wheel drive . . . and one that's power-matched throughout.

DANA CORPORATION • Toledo 1, Ohio

DANA PRODUCTS Serve Many Fields:

AUTOMOTIVE: Transmissions, Universal Joints, Propeller Shafts, Axles, Powr-Lok Differentials, Torque Converters, Gear Boxes, Power Take-Offs, Power Take-Off Joints, Clutches, Frames, Forgings, Stampings.

INDUSTRIAL VEHICLES AND EQUIPMENT: Transmissions, Universal Joints, Propeller Shafts, Axles, Gear Boxes, Clutches, Forgings, Stampings.

AVIATION: Universal Joints, Propeller Shafts, Axles, Gears, Forgings, Stampings.

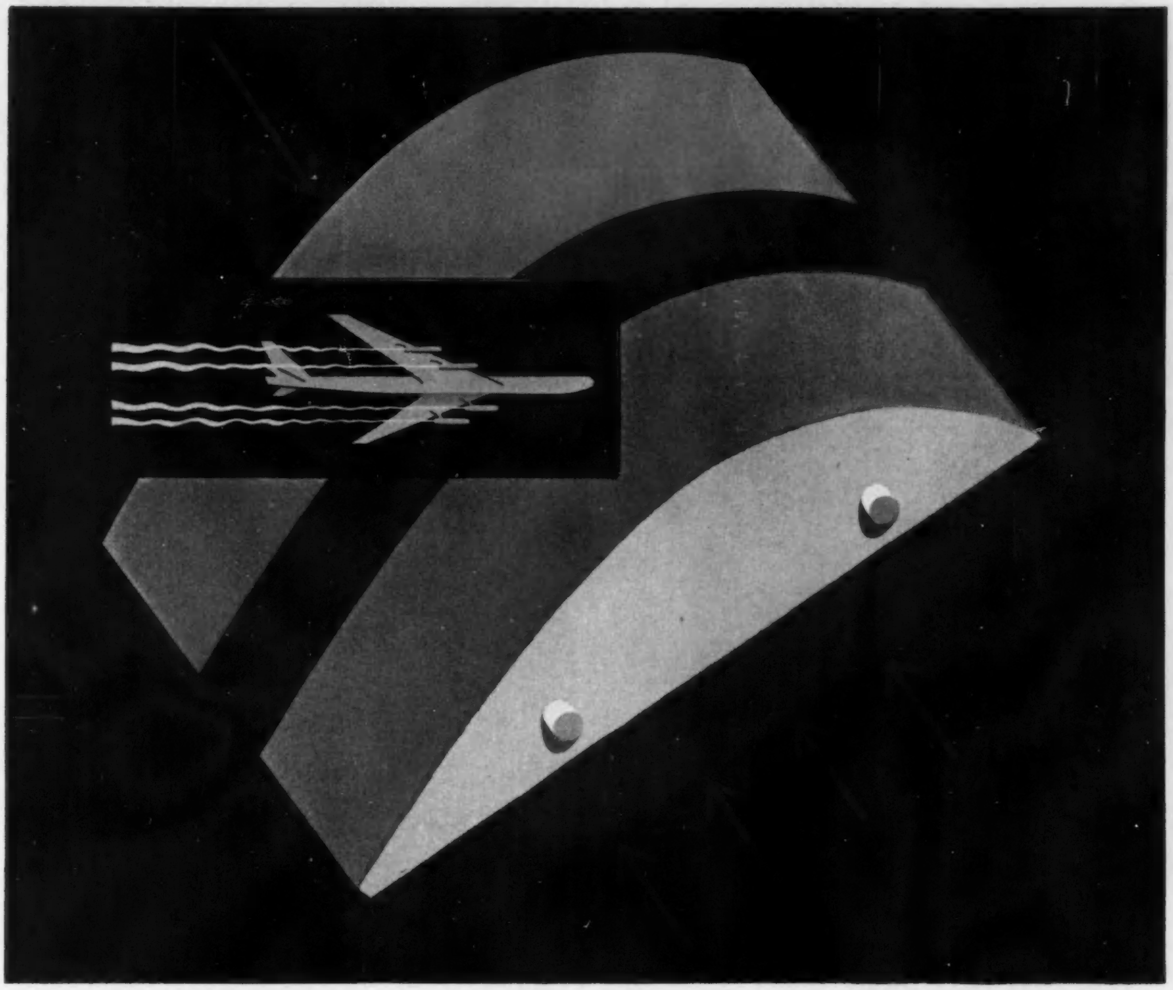
RAILROAD: Transmissions, Universal Joints, Propeller Shafts, Generator Drives, Rail Car Drives, Pressed Steel Parts, Traction Motor Drives, Forgings, Stampings.

AGRICULTURE: Universal Joints, Propeller Shafts, Axles, Power Take-Offs, Power Take-Off Joints, Clutches, Forgings, Stampings.

MARINE: Universal Joints, Propeller Shafts, Gear Boxes, Forgings, Stampings.

Many of these products manufactured in Canada by Hayes Steel Products Limited, Merritton, Ontario.

DANA Spicer



Save up to 30% in cost, 60% in time with EPON RESIN tools and dies

Your tooling resin formulator will show you how Epon resin formulations save time and money in applications such as these:

High temperature tooling: Metal forming stretch dies that can operate at temperatures over 400°F.

Heated tools: Matched dies, with integral heating units, may be made with Epon resin formulations for rapid heat curing of laminated plastic parts.

Long-lasting metal forming tools: Castings made of formulated Epon resin, mounted in a crank press, showed no permanent deformation after 28,000 compression-shock cycles.

In addition, Epon resin formulations offer you the following advantages:

Excellent tolerance control: Little machining and handwork are required to finish Epon resin tools because of the material's excellent dimensional stability and lack of shrinkage.

Outstanding strength: Jigs and fixtures with thin cross sections can be built from Epon resin-based formulations reinforced with glass cloth. The resulting laminate has high flexural strength and excellent dimensional stability.

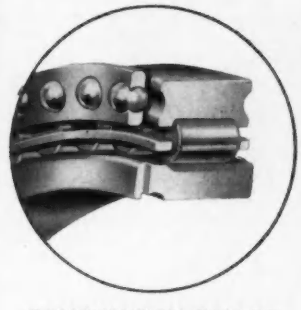
Easy modification: Tools and fixtures made from Epon resins may be quickly and easily modified to incorporate design changes.

CONTACT YOUR TOOLING RESIN FORMULATOR

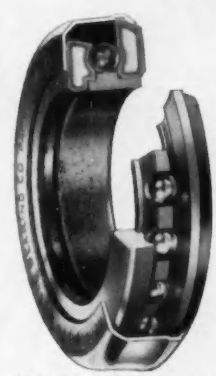
The combination of resin formulator's skill and practical knowledge, backed by Shell Chemical's technical research and experience, has solved many important tooling problems for industry. Your own formulator specialist can help you solve yours. For a list of experienced tooling resin formulators and additional technical information, write to:

SHELL CHEMICAL CORPORATION
PLASTICS AND RESINS DIVISION
50 WEST 50th STREET, NEW YORK 20, NEW YORK
CHICAGO • CLEVELAND • LOS ANGELES • NEW YORK
IN CANADA Chemical Division, Shell Oil Company of Canada, Limited, Montreal • Toronto • Vancouver

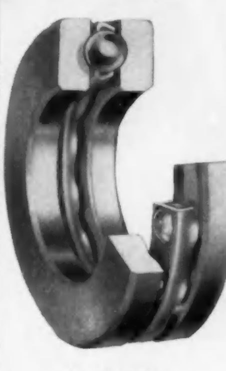
SHELL



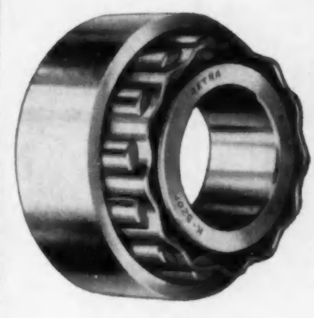
COMBINATION ROLLER AND BALL BEARING



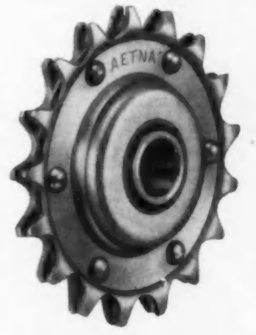
CLUTCH RELEASE BEARING



THRUST BEARING



ROLLER BEARING



STANDARD SPROCKET IDLER UNIT

Aetna "Firsts"

DETACHABLE LINK IDLER UNIT

Aetna engineers have that inquiring type of mind which is constantly seeking—constantly asking itself questions—constantly developing new and better ways of doing things.

This creative engineering approach has resulted in an imposing record of Aetna "firsts".

1st to combine cylindrical roller and ball thrust in a single bearing to divorce the load into pure radial and pure thrust for extremely heavy duty service

1st in sales of clutch release bearings for mobile on-and-off the road vehicles—first for more than a quarter-century

1st with a complete line of precision-built thrust bearings to meet practically every load, speed and application requirement

1st to standardize on true crown rollers for all roller bearings to secure the best load distribution of load stresses for far longer service life—permanently assembled in retainers of a type which maintains alignment and correct spacing

1st to combine a roller chain sprocket idler and pre-lubricated ball bearings in a single, compact, easy-to-install single package unit

1st ball bearing detachable link sprocket idler with a full complement of ball bearings, self-contouring seals and sturdy sprocket wheel

Take advantage of this creative engineering talent and Aetna's diversified production facilities. Call your local representative listed in the yellow pages of your Classified Phone Book, or write direct for New 15th Edition Catalog and Engineering Manual.

AETNA BALL AND ROLLER BEARING COMPANY

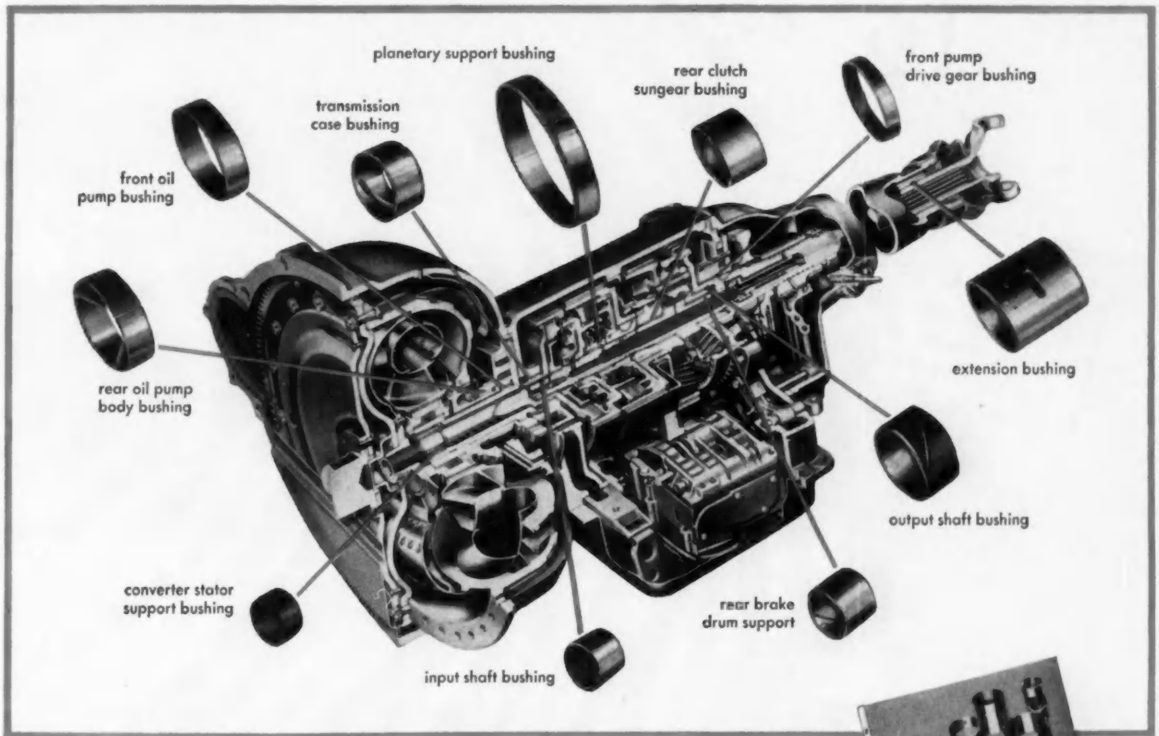
DIVISION OF PARKERSBURGH-AETNA CORPORATION • 4600 SCHUBERT AVE. • CHICAGO 39, ILL.

IN DETROIT—SAM T. KELLER, 1212 FISHER BUILDING

Aetna ANTI-FRICTION CONSULTANT TO LEADING ORIGINAL EQUIPMENT MANUFACTURERS SINCE 1916

FORMED BUSHINGS...

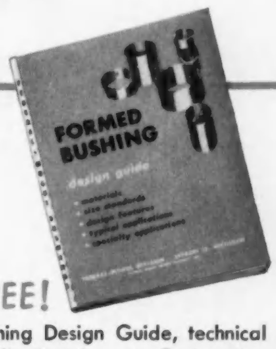
versatile performers for the design engineer!



This automatic transmission shows some typical applications of Federal-Mogul formed bushings. There are many others, in related areas. Actually, the formed bushing's field of usefulness extends into every assembly involving shaft movement or positioning.

We produce to your specifications, in solid bronze or bimetal. We incorporate your design features—oil grooves or holes, cut-outs, seams, chamfers, ball indentations.

Through our specialized production facilities, the design engineer can solve *both* of his major problems—dependable performance and economical cost!



FREE!

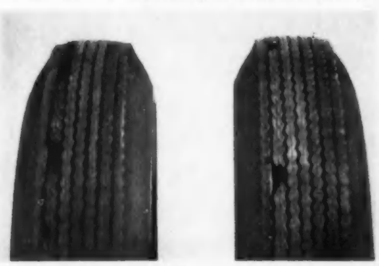
Bushing Design Guide, technical publication by our Engineering Department. Shows materials, size standards, design and application features. Write today!

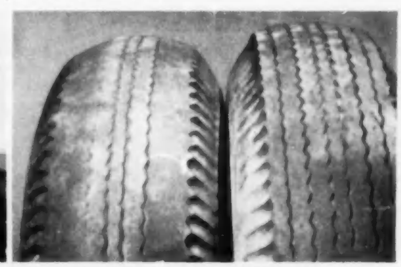
FEDERAL-MOGUL DIVISION

FEDERAL-MOGUL-BOWER BEARINGS, INC., 11035 SHOEMAKER, DETROIT 13, MICHIGAN

SELL MORE TIRE POWER

1 *PROVED AT HIGHER THAN TURNPIKE SPEEDS*
Laboratory tests had indicated that TYREX viscose tire cord showed superior performance qualities at higher temperatures than nylon. To prove it, an independent tire testing company conducted a series of road tests over a hot, abrasive pavement at speeds up to 128 miles per hour.





60% LESS CHUNK OUT!

2 At these far-greater-than-normal speeds tread chunking naturally occurred. But the number of linear inches of tread chunking on nylon tires was 2½ times as much as on tires made with TYREX viscose cord.

77% LESS GROWTH!

3 The combination of high speed and high temperatures (tire temperatures rose to over 200°) affected the nylon cord more than the TYREX viscose tire cord. The nylon tires showed 3 times as much growth.

24% LONGER TREAD LIFE!

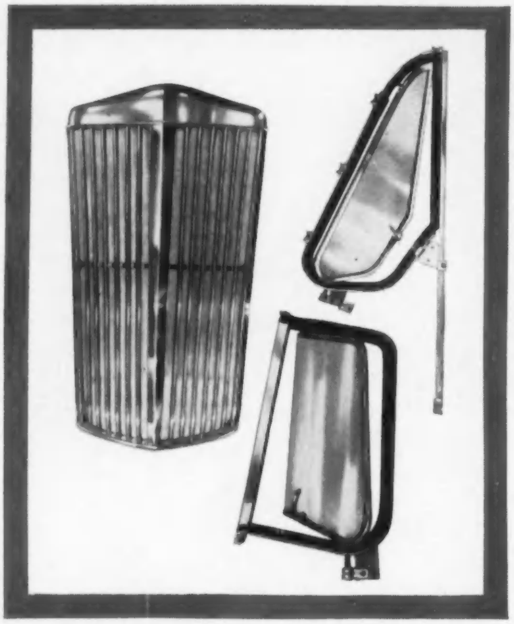
4 At the end of this grueling series of tests, careful measurements of all the tires showed that the tires containing TYREX viscose tire cord delivered 24% greater tread mileage than the tires made with nylon.

Give your customers more tire power with TYREX viscose tire cord—the tough new cord that makes any tire run cooler, softer, quieter and safer . . . with no morning thump.

*TYREX INC., Empire State Bldg., New York 1, N. Y. *TYREX is a certification mark of TYREX Inc., for viscose tire cord and yarn. TYREX viscose tire cord and yarn is also produced and available in Canada.*

Problem-Solving Products from Republic

FUNCTIONAL STAINLESS STEEL IS CORROSION-RESISTANT, STRONG, WEIGHT-SAVING, READILY FORMED



The high strength-to-weight ratio of stainless steel permits the use of slimmer channels and frames in passenger car and truck sash. Protected by stainless, glass breakage is less likely. Strength, dent-resistance, and corrosion-resistance make stainless ideal for radiator grills. Manufacturer—Excel Corporation, Elkhart, Indiana.

Always right, always bright stainless steel, the optimum metal for trim and brightwork, is showing up in ever-increasing functional applications.

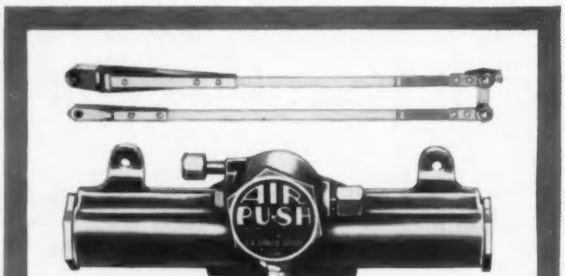
The reason? Stainless steel offers automotive part and equipment manufacturers and designers a combination of qualities unobtainable in any other commercial metal.

Stainless steel parts are tough and strong, yet lightweight. They offer outstanding resistance to heat, wear, and abrasion. They stubbornly resist rust and corrosion. Maintain their great strength through extremes of heat and cold.

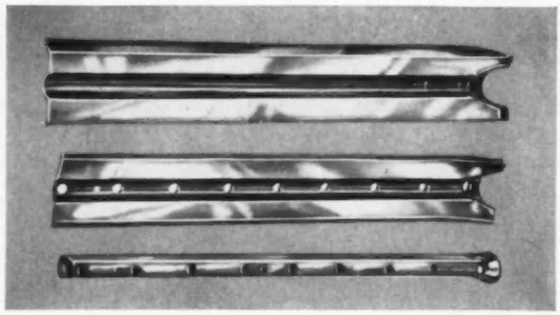
Stainless is readily formed into desired shapes and designs on present equipment with little or no change in procedure and often at lower ultimate cost. Conventional welding techniques, currently in use on production operations, permit the combining of strong, lightweight stainless to carbon steel panels. The result is an over-all reduction in weight without loss of strength or safety, and a structural member that is both functional and decorative.

The functional stainless steel parts and equipment illustrated on these pages represent only a few of many current applications. Others include: mufflers, head gaskets, exhaust manifold butterfly valves, fasteners, heat exchangers. Future applications are practically unlimited.

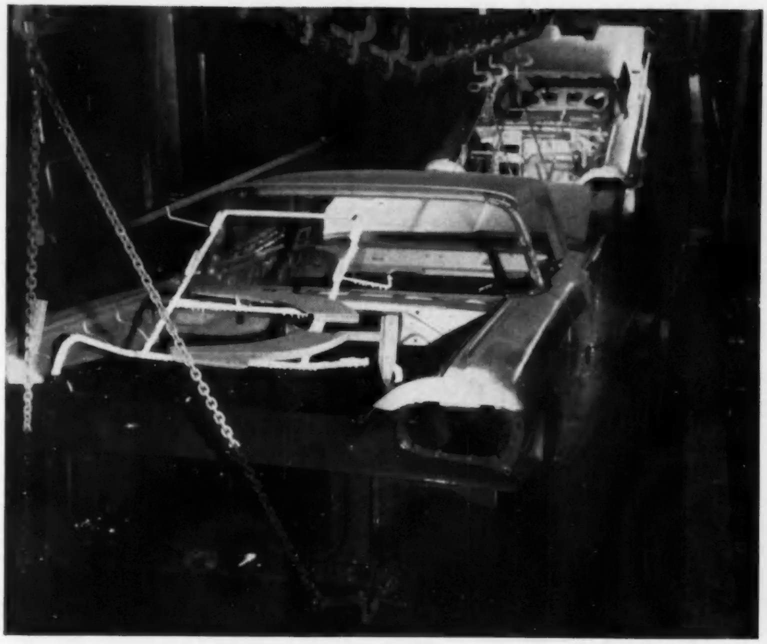
Republic Stainless Steel metallurgists and engineers are always available for consultation on development, selection, application and processing. No obligation for their services. Just mail the coupon.



Stainless steel makes an important contribution to the safe operation and maintenance of windshield wipers. Stainless steel's strength assures resistance to breakage or distortion. Light, strong design reduces dead weight that the wiper motor must move. Elasticity of stainless gives the blade the proper pressure on the glass. The wiper arms are protected against the slow and insidious weakening effects of corrosion. Manufacturer—Sprague Devices, Inc., Michigan City, Indiana.



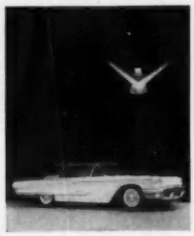
Formability, corrosion-resistance, and cost were prime factors in switching to stainless steel from brass in this engine water distribution tube. Stainless was easily fabricated on existing tools. It took the constant flow of hot water and anti-freeze chemicals in stride. The greater strength of stainless virtually eliminated loss from bent or damaged tubes. Photo sequence shows fabricating operations: (1) Blank of .010″ stainless strip after initial drawing and embossing, (2) Same blank after piercing of water outlet holes trimming of flanges, (3) Completed tube after roll-forming and lock seaming. Produced by Pontiac Motor Division of General Motors Corporation.



LATEX PRIMER *lessens paint-line fire hazard*

The threat of fire dwindles to near-zero when the paint primer used is formulated with Dow Latex. With these water-thinned primers, the cost of maintaining fire prevention facilities goes way down—and so can fire insurance rates. What's more, objectionable solvent fumes are gone and costly solvent recovery systems are no longer necessary.

Latex primers give outstanding rust protection, too. Some of the hundreds of hidden metal parts in the car's understructure are guarded by baked industrial finishes of higher molecular weight that are locked to the metal by a unique chemical reaction. Not even corrosive salt spray can penetrate the tough latex finish. Latex primers represent an important advance in production line safety and economy. Three other Dow plastics make important contributions to designing and manufacturing progress, too. They're described briefly at left.



* * *

For further information on the many fine Dow plastics and coatings of special interest to the automotive industry, contact THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Dept. 1704-EN6.

MORE NEWS
of Dow automotive ideas in action

LIGHTER COLORS, NEW WEAVES and patterns are made completely practical with Dow Latex 2582 in the backing formulations. Its good light color characteristics make possible more varied weaves and fleck patterns . . . and it's highly resistant to copper and other metal dye stains, as well as to fading and aging.

PREMIX PLASTIC MOLDINGS made with Dow Styrene or Vinyltoluene make better, stronger housings for automobile heaters. Preblending of fibers and resins means uniform strength throughout the unit.

MANY TIMES TOUGHER and more durable than concrete, floor surfaces of epoxy mortars are perfect for in-plant locations where floors take a real beating. They can be feather-edged, too.

DOW PLASTICS BASIC TO THE AUTOMOTIVE INDUSTRY

Molding Materials • Coatings

Extrusion Materials • Sheeting

Fabric Resins

THE DOW CHEMICAL COMPANY

MIDLAND, MICHIGAN

DOW

NOW — a New Temperature Sensitive

EATON VISCO-DRIVE

— a Thermostatically Controlled Fan Drive that Increases Usable Horsepower and Reduces Fan Noise

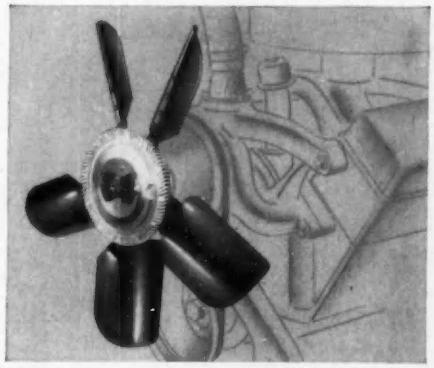
WHEN COOLING IS NOT REQUIRED: The fan idles when under-hood temperature is below the thermostatic setting. The slide-valve is closed preventing fluid from entering the viscous-drive chamber.

WHEN COOLING IS REQUIRED: Fan speed increases with rise in under-hood temperature. Thermostatically controlled slide-valve regulates the amount of fluid entering the drive chamber, increasing fan rpm accordingly.

The new Eaton Visco-Drive is automatically regulated by under-hood temperature. As under-hood temperature rises, the Visco-Drive automatically increases fan rpm to produce required cooling. Operational ranges can be established to suit the requirements of each vehicle model.

Thermostatically-modulated fan operation increases net output of engine when cooling is not needed; permits designing for greater cooling efficiency at low engine speeds without the disadvantage of fan noise at high speeds.

The Eaton Visco-Drive is of simple, functional design and light-in-weight construction. Field and laboratory tests have proven its dependability for application on all types of vehicles.



Ultra-compact design makes the Visco-Drive readily adaptable to your present installation with only minor changes.

Torque-Sensitive Eaton Visco-Drives are also Available.
Consult with Our Engineers on Your Fan Drive Needs.

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